II Encontro Biotecnologia e Agricultura: O Futuro é Agora

More sustainable foods: some Transgenic Seeds in Organic Agriculture?

Mertxe de Renobales Scheifler

Biochemistry and Molecular Biology - Pharmacy

Univ. País Vasco / Euskal Herriko Unib.

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Transgenic Seeds in Organic Agriculture

- characteristics of Organic Agriculture
  - nutritional properties of organic foods
  - sustainability
- why does OA reject transgenic seeds?

- improving the plants that we eat

- what can transgenic seeds contribute to Organic Agriculture?

- transgenic seeds in OA – why not?
Characteristics of Organic Agriculture

◆ system for food production that seeks to maintain an equilibrium between production and nature protection

◆ for some: a philosophy of life

◆ for others: an economic opportunity because the price of organic products is approx. double that of conventional foods.

Briz, Agricultura ecológica y Alimentación, 2004
Characteristics of Organic Agriculture

◆ we consider "organic agriculture" as regulated in Europe by:

• Council Regulation 834/2007 on organic production and labelling
• Council Regulations 889/2008 and 1254/2008

• official label of organic agriculture products: mandatory since July 1st, 2012

◆ the official label ONLY certifies:

• production system was in accordance with the above Regulations
Characteristics of Organic Agriculture

♦ most consumers consider that OA is sustainable because it does not use synthetic herbicides and pesticides, and soluble fertilizers. Tipología y perfil sociodemográfico del consumidor de alimentos ecológicos en España - GfK and Ministerio Medio Ambiente, 2011
http://es.scribd.com/doc/74696959/Estudio_Perfil_or_Alimentos_Ecologicos

• same is true in Europe and in the USA

• is it really more sustainable?

♦ positive aspects of OA:
• ↓ energy, fuel, synthetic agrochemicals
• ↓ soil and water contamination with certain agrochemicals
• ↓ mechanization and tilling
• crop rotation
• ↑ soil organic matter and soil fertility

(Altieri, La Agroecología, 1999)
Characteristics of Organic Agriculture

◆ less positive aspects:
  • deficient weed and pest control
  • suboptimal availability of N at important moments of crop development  
    Trewavas, *Crop Protection* 23, 757, 2004;  
  • ⇒ productivity?
    ▪ meta-analysis  
      Seufert et al., Nature doi: 10.1038/nature11069, 2012
      13 – 34% ↓: average, 25% ↓
      - highly variable: it depends on many factors
    ▪ other studies:
      - productivity: 20–30% ↓ than conventional agriculture
        (variable data depending on crops)
      Goulding & Trewavas, AgBioWorld, 2009;  
      Mäder, *Science* 296,1694, 2002;  
      Univ. Calif. Davis, "Tomorrow's Table", 2008
Characteristics of Organic Agriculture

- average yield of organic vs. conventional crops:
  25% less

Seufer et al., Nature 2012

- it needs 25% more land to produce the same amount!

where does the extra land come from?
Characteristics of Organic Agriculture

Most consumers think that OA foods are healthier, more nutritious, and less contaminated. 

Regulation 834/2007 does NOT imply that organic products are more nutritious, healthier, or tastier than non-organic foods.

- no obligation to evaluate nutritional or sensory quality before commercialization
Characteristics of Organic Agriculture

◆ nutritional quality of organic foods

• ↓ concentration of synthetic herbicides and pesticides
  (EFSA, Scientific report 305. 2009)

• may have higher concentrations of other products: Cu, rotenone, etc…

• may have higher levels of pathogenic microorganisms:
  ▪ authorized fertilizer: composted manure
    - composted for over 1 year
  ▪ 2006: spinach (California): E.coli 0157:H7 – 3 deaths
  ▪ 2011: fresh sprouts (Germany) – 40 deaths
Characteristics of Organic Agriculture

◆ nutritional quality of organic foods (cont.)
  • ↑ concentration of fumonisins (carcinogenic micotoxins) in corn and derived products (Rapid System Alert of the EU)
    ▪ 2003 - 2008: >60 batches of corn products were removed from markets, ≈ 30% were organic corn products and ≈ 70% were conventional
    (http://ec.europa.eu/food/food/rapidalert/index_en.htm)
    - corn borer resistant corn (MON 810) has practically NO fumonisins
      ▷ importance for people with cealiac disease
Characteristics of Organic Agriculture

◆ nutrient content: very variable

• study by the Food Standards Agency (United Kingdom, 2009)
  ▪ extensive bibliographic review of the last 50 years:
    - no significant differences between organic and conventional crops

• several other studies
  ▪ no significant differences between organic and conventional crops
    (Caris-Veyrat, Journal of Agriculture and Food Chemistry 52, 6503, 2004)
    (Rosen, Comprehensive Reviews in Food Science and Food Safety 9, 270, 2010)

★ Organic Crops are nutritionally equivalent to Conventional Crops ★
Characteristics of Organic Agriculture

most consumers think that OA products are NATURAL, not manipulated by humans:

- Regulation 834/2007 prohibits the use of transgenic seeds because they are perceived as "not natural" by consumers of organic products and are considered incompatible with the concept of organic production (Whereas Clauses 1 and 9, Regulation 834/2007)

- no further explanation is provided
- 0% GM required for organic label

- are the seeds OA uses really natural?
Why does OA reject transgenic seeds?

- the concept of "natural"....

- **what is a "natural substance" and a "natural process"?**
  - "non synthetic", "not man-made", "not manipulated by humans"
  - "obtained from nature as it is"
  - "traditional", "as our ancestors did", "grandma's foods"
  - etc....

- **how many of the plants we eat**
  - have not been manipulated by humans?
  - have the same genome as they did 10,000 years ago?

- **OA allows ripening in trucks while in transit**
  - is this a natural process?
Why does OA reject transgenic seeds?

is the rejection of transgenic seeds
• reasonable?
• based on scientific principles and data?

is the genome of seeds used in OA NOT modified by humans?
• recent studies: new analytical technologies: genomics, transcriptomics, proteomics, metabolomics
• much greater gene alterations in plants obtained by induced mutagenesis than by transgenesis

(Batista y cols. PNAS 105: 3640-3645, 2008 - arroz)
(Coll y cols. Plant Mol Biol 68, 105, 2008 y refs citadas - maíz)
(Ammann, New Biotechnology 25, 101, 2008)

let's review how we improve the plants we eat
Improving the plants we eat

◆ hybridization, or crossing: basic technique for plants that are closely related
  • to pass the characteristics of plant A to plant B:

* how does plant A acquire the characteristic we want?
Improving the plants we eat

- desired characteristic introduced by:
  - mutations (small changes in the DNA of the plant):
    - spontaneous: occurring in nature
  - introduced in the laboratory (induced mutations)
    - treatment with mutagenic chemicals
    - irradiation with radioactive compounds
    - cosmic radiations and microgravity (spaceships)
    - somaclonal variations: \textit{in vitro} cultures
  - other laboratory techniques:
    - changes in the number of chromosomes: treatment with colchicine (obtained from autumn crocus)
    - cell fusion (protoplasts)
    - forced hybridization with embryo rescue

- conventional, non-transgenic (legal point of view)

- genetic engineering (transgenic)
  - molecular biology and genetic engineering techniques (lab)
Improving the plants we eat - conventional

- some crops developed by conventional techniques

- selection of different characters

- spontaneous mutation

- \( \gamma \) radiation-induced mutation

- triticale: intergenic hybridization and chromosome duplication (hexaploid)

- chromosome duplication: octaploid strawberries
Improving the plants we eat - conventional

traditional hybridizations

variety 1
30,000 genes each

x

variety 2

Hybrid 1
30,000 genes randomly mixed

courtesy of Prof. Dr. Carmen Fenoll

Hybrid 2….
Improving the plants we eat

• OA accepts plants improved by all conventional techniques including:
  • induced mutagenesis by treatment with mutagenic chemicals, and irradiation:
    ▪ FAO-Int'l Agency for Atomic Energy: joint program to improve seeds
      - > 2,600 varieties improved, > 180 species
      - see next slide
  • chromosome duplication with colchicine, etc…

• non-acceptable conventional technique:
  ▪ protoplast fusion (does not occur in nature!!)
Improving the plants we eat

“Useful mutants bred by radiation” – New York Times, August 28, 2007:

Here to Stay

More than 2,500 mutant crop varieties have been officially registered with the United Nations and the International Atomic Energy Agency. About three-quarters of the varieties were directly induced by gamma radiation.

Source: F.A.O./I.A.E.A. Mutant Variety Database
Improving the plants we eat - transgenics

- general scheme to make a transgenic plant

1) Se identifica...
...el gen que nos interesa:
de un ser vivo
(bacteria, planta...)

2) Se aísla...
...el gen de interés

3) Se integra...
...el gen de interés
en una construcción genética

4) Se multiplica
la construcción genética

5) Se transfiere...
...el gen a la planta
que queremos modificar

6) Se seleccionan...
las células que han
incorporado el nuevo gen

7) Se regenera...
...con ellas una
nueva planta

8) Se analiza...
...si el nuevo gen se ha
incorporado a la planta

Improving the plants we eat - transgenics

- *in vitro* development of plants that incorporated the desired gene
Improving the plants we eat - transgenics

- selection of desired plants in the greenhouse
- field trials (after securing authorization)

Industrial greenhouse at Syngenta

insect resistant transgenic corn

conventional corn

photograph: courtesy of Dr. Jaime Costa
Improving the plants we eat - transgenics

1 transgenic plant ➜ many commercial varieties by hybridization and backcrossing

88 variedades de maíz MG derivadas de MON-ØØ81Ø-6 están autorizadas para su comercialización en España (mayo 2008)

<table>
<thead>
<tr>
<th>Empresa comercializadora</th>
<th>Variedad (fecha de autorización en BOE o en el Catálogo Europeo)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pioneer Hi-Bred</strong></td>
<td>PR33P67 (11/03/03), PR32P76 (16/02/04), BACILA (11/08/05), PR32R43 (11/08/05), PR32W04 (11/08/05), PR34N44 (11/08/05), PR36R11 (11/08/05), PR31N28 (07/09/06), PR33B51 (07/09/05), PR35B09 (07/09/06), PR31D21 (25/04/08), PR31D61 (25/04/08), PR31P43 (25/04/08), PR32T66 (25/04/08), PR35Y68 (25/04/08), ELGINA (17/09/04), OLIMPICA (17/09/04), BOLSA (17/09/04), LEVINIA (17/09/04), PR33FT1 (21/04/06), PR39V17 (21/04/06), PR33DF66 (22/06/06), PR39DF52 (28/08/07), PR38A25 (29/08/07), PR32G49 (15/04/08), PR32K52 (16/04/08), PR39T47 (30/04/08)</td>
</tr>
<tr>
<td><strong>Monsanto Agricultura</strong></td>
<td>DKC 8575 (11/03/03), DKC 8580 (16/02/04), DKC4424YG (11/08/05), DKC5754YG (11/08/05), DKC6041YG (11/08/05), DKC6518YG (07/09/06), DKC6531YG (06/10/05), DKC8419YG (11/05/07), DKC6451YG (11/05/07), DKC6667YG (11/05/07), DKC6844YG (11/05/07), TABALA YG (25/04/08), DKC513 (17/09/04), DKC3421YG (21/04/06), DKC3946YG (28/08/07), DKC2950YG (30/04/08)</td>
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<tr>
<td><strong>Limagrain Ibérica</strong></td>
<td>ALIACAN BT (11/03/03), ARISTIS BT (11/03/03), GAMBIER BT (16/02/04), CAMPERO BT (16/02/04), HELEN BT (11/08/05), BELES SUR (07/09/06), LUSON BT (07/09/06), VRIATO BT (07/09/06), ASTURIAL BT (07/09/06), ABREGO BT (07/12/06), PONCHO YG (11/05/07), THURRO YG (11/05/07), LG3171Y (25/04/08), NOVELIS (17/09/04), LG3233YG (28/08/07)</td>
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<tr>
<td><strong>Semillas Fitó</strong></td>
<td>JARAL BT (16/02/04), SF1035T (11/08/05), SF1036T (11/08/05), SF112T (11/08/05), SF4701T (07/09/06), AZEMA YG (07/09/06), CARELLA YG (25/04/08)</td>
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<tr>
<td><strong>Arlesa (Euralis)</strong></td>
<td>CUARTAL BT (16/02/04), RIGLOS BT (11/08/05), ES MAYORAL YG (25/04/08), ES ARCHIPEL YG (25/04/08), ES CAJOU YG (25/04/08), ES PAOLIS YG (25/04/08), ES ZODIAC YG (25/04/08),</td>
</tr>
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<td><strong>Koipesol</strong></td>
<td>PROTECT (16/02/04), KAPER YG (23/03/07)</td>
</tr>
<tr>
<td><strong>Agrar Semillas</strong></td>
<td>FOGGIA (11/08/05), MAS 60YG (11/05/07), MAS 58Y (25/04/08), MAS 71YG (25/04/08)</td>
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<tr>
<td><strong>Corn States Int.</strong></td>
<td>EVOLIA YG (07/09/06), BENJI YG (07/12/06), KOFOPI YG (07/12/06), ROCCO YG (07/12/06), PLACIDO YG (23/03/07), TONIC YG (11/05/07),</td>
</tr>
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<td><strong>KWS</strong></td>
<td>KKA5491 YG (11/05/07), KURATUS (22/06/06)</td>
</tr>
<tr>
<td><strong>Causseade Semences</strong></td>
<td>VENICI YG (25/03/07)</td>
</tr>
<tr>
<td><strong>RAGT</strong></td>
<td>RUGBYXX YG (25/04/08)</td>
</tr>
</tbody>
</table>
Improving the plants we eat - transgenics

Variety A
30,000 genes
courtesy of Prof. Dr. Carmen Fenoll

Variety A*: transgenic
30,001 genes

conventional rice

"Golden Rice":
↑ provitamin A

(2, 3, or a few genes)
Transgenic Crops in 2011

GLOBAL AREA OF BIOTECH CROPS
Million Hectares (1996-2011)

A record 16.7 million farmers, in 29 countries, planted 160 million hectares (395 million acres) in 2011, a sustained increase of 8% or 12 million hectares (30 million acres) over 2010.

Source: Clive James, 2011.

http://www.isaaa.org
Transgenic Crops in 2011

Source: Clive James, 2012
Transgenic Crops in 2011

◆ already authorized (in many countries)
  • improving agronomic properties
    ▪ insect resistant, herbicide tolerant: corn, soya, cotton,…
    ▪ virus and disease resistant: papaya, cucumber, squash,
    ▪ drought tolerant: corn, wheat,
  • under development:
    - tolerant to saline, acidic soils: corn, soya, etc…
    - more efficient use of N

• improving nutritional properties (still not authorized)
  ▪ ↑ concentration of β-carotenes (Golden Rice)
  ▪ healthier fats: rapeseed, sunflower
  ▪ ↑ antioxidants: tomato, corn, yucca (mandioca)
  ▪ hypoallergenics: peanut, rice
  ▪ etc…. 
Contributions of Transgenic Seeds

* to the health of consumers
  - Directive 2001/18/EC
  - Regulation EC 1829/2003
  - rigorous evaluation BEFORE authorization to commercialize
  - allergenicity of new protein(s)
  - toxicity of inserted gene(s), protein(s), other compounds
  - nutritional quality


★ all transgenic plants (and foods) commercialized to date have passed all the toxicity and allergenicity tests
★ nutritionally equivalent to their conventional counterparts
Contributions of Transgenic Seeds

WHO, FAO, National Academy of Sciences of the USA, EFSA, the Royal Society (UK), American Medical Association, American College of Nutrition, American Society of Toxicology, Union of German Academies for Sociology and Humanities, etc.... declared that:

★ commercialized GM crops are as safe (or as unsafe) as conventional crops ★

★ commercialized GM crops do not present any more risks for the health of consumers than conventional crops ★

and in some cases, GM crops are better .....
Contributions of Transgenic Seeds

- incidence of *Ostrinia* and *Sesamia* in Portugal

- insect resistant (Bt) crops:
  - produce their own insecticide
  - protein from *Bacillus thuringiensis* (Bt)
    - only 1 bacterial protein in GM corn
  - Bt: authorized insecticide for OA
    - formulations include millions and millions of the complete bacterium
Contributions of Transgenic Seeds

◆ to the environment
◆ ▼ pesticides: "Bt crops"


in 2006: ▼ > 55 million kg of active compound
▼ 77% insecticidas

(Quaim, 2005)
Contributions of Transgenic Seeds

❖ **O. nubilalis** in conventional fields **thanks to nearby fields of Bt corn**
  
  *Hutchinson et al., Science 330, 222, 2010*

❖ also observed in **cotton fields in China**
  
  *Wu et al., Science 321, 1676, 2008*

**coexistence problems?**
Contributions of Transgenic Seeds

- **productivity:** due to **losses,** with no extra inputs
  - insect resistant and virus resistant crops:
    - 10 - 15% productivity (average)
    - 50% productivity in cases of severe infestations

Gonsalves, AgBioForum 7, 36-40, 2004; Huang et al, Science 308, 688-690, 2005
JR Park y cols, Plant Biotech J, 2010

Salvia et al., 2008
Bt corn in Catalonia, Spain
Contributions of Transgenic Seeds

- herbicides of high environmental impact


- glyphosate ⇒ contamination of aquifers
  - less toxic, less persistent in nature
  - low environmental impact
  - low toxicity for vertebrates
    - LD50 glyphosate > LD50 aspirin and caffeine
Transgenic Seeds in OA – Why not?

◆ contradictions of OA in Regulation 834/2007:

- involuntary presence of small amounts of synthetic agrochemicals is allowed
  - but NO involuntary presence of GMO
  - why continue to maintain the 0% GM requirement?

- use of *B. thuringiensis* (whole bacterium) as insecticide is allowed
  - but NO Bt plants with only 1 or 2 genes from Bt.

- use of seeds genetically modified by induced mutagenesis (with an unknown number of mutated genes)
  - but NO GMOs with only 1-5 different genes

- use of transgenic veterinary medicines is allowed (Art. 2),
  - but NO Bt plants with NO fumonisins
Transgenic Seeds in OA – Why not?

- **NO scientific reasons** for rejecting the use of genetically modified seeds in OA

- **NO scientific reasons** for maintaining the 0% GM requirement for the organic label

  fundamental, ideological reasons....

  elite consumers (high prices)
Transgenic Seeds in OA – Why not?

why not use *certain* transgenic seeds in OA?:

• ↑ sustainability: those that do NOT need agrochemical products, and ↑ productivity by reducing losses: ↓ cultivated land
  ▪ insect resistant, virus resistant
  ▪ drought tolerant,
• with nutritional improvements
• as “natural” as the rest of conventionally produced seeds
• better for consumers' health: NO fumonisins

• all these are compatible with the philosophy of OA and allow to ↑ its productivity

we do not insist on the use of herbicide tolerant crops in spite of their positive contributions to the environment.
Transgenic Seeds in OA – Why not?

◆ need to overcome ideological barriers, on both sides, basing our decisions on scientific data

• transgenic side:
  ▪ the practice of OA can contribute positive aspects to agriculture

• organic side:
  ▪ transgenic seeds can reduce the environmental impact of agriculture and contribute nutritional advantages to consumers' health

★ major effort ★
Transgenic Seeds in OA – Why not?

◆ ultimate objective

- let's avoid unnecessary conflicts and use our intelligence and resources to find solutions:
  - panaceas do NOT exist on earth.

- use the best of all technologies available to look for the most appropriate solutions for people and the environment:
  - according to the characteristics of each region
  - can we afford NOT to use transgenic seeds?

(Godfray et al., Science 236, 812-818, 2010)
Transgenic Seeds in OA – Why not?

◆ some social benefits

- ↑ competitiveness of our European farmers and meat producers
  - European agriculture productivity is 15% lower than that of USA
    (Collier, The politics of hunger, *Foreign Affairs* 87, 67, 2008)
  - meat producers: ↑ of cost of feeds
    - release "zero tolerance level" for events not yet authorized in Europe.

- do not block adoption of biotechnological crops in Africa
    - important ↑ in the local production of food
  - overcome self-imposed restrictions to maintain organic exports to Europe: starvation in Zambia in 2002-2003
    (Paarlberg, *Starved for Science: how biotechnology is being kept out of Africa*, 2008)
Transgenic Seeds in OA – Why not?

◆ similar proposals by various authors:

- Ronald y Adamchak: *Tomorrow’s Table*, 2008
- Conway: *Times on Line*, 13 de enero de 2010

  in English: [http://www.sibi.org/jpg/ingles/92009.html](http://www.sibi.org/jpg/ingles/92009.html)
Transgenic Seeds in OA – Why not?

Wilson's working on a gene program that will make genetically modified vegetables 100% organic.
Muito Obrigada!

Thank you very much for overcoming ideological barriers

Any questions?
Sustainability in Agriculture

◆ Bruntland report ("Our common future", 1987):

_to satisfy the needs of the present without compromising the ability of future generations to satisfy their needs_

◆ implications of sustainability:

- responsibility towards the environment
- responsibility towards present and future generations
  - social issues
  - economic issues

  H. Jonas, _Imperative of Responsibility_ (1985)

- institutional and government support
  we are all moving in the same direction
Sustainability in Agriculture

◆ responsibility towards the environment
  • ↓ energy consumption
  • rational use of water, fertilizers, pesticides, herbicides
  • without increasing the cultivated land (1.500 million Ha)

◆ responsibility towards present generations in Europe
  • ability to earn a living: farmers, meat producers
    ▪ right to choose what farmers plant
  • development of rural areas: standard of living
  • cost of foods for consumers
    ▪ nutritious foods at a reasonable price
Contributions of Transgenic Seeds

- **cultivos tolerantes a herbicidas: facilitan la gestión de los cultivos**
  - menos aplicaciones, menos gasoil, menos emisiones de CO₂:
    - 2007: 1.9 millones de coches menos durante 1 año (USA)
  - ⇒ facilitan la agricultura de conservación
    - soja: 64% ↑ superficie sin laboreo; 58% agricultores
    - maíz: 20% ↑ superficie sin laboreo
    - algodón: 371% ↑ superficie sin labo.; 80% agricultores

Some GM seeds in OA – Why not?

- very few GM crops authorized in the EU
  - import: soybean, corn, oilseed rape, cotton, potato, sugar beet.
  - cultivation: corn, potato.

Approvals of GMOs in the European Union – EuropaBio - 2011
Aspectos Sociales de la Agricultura Ecológica (cont.)

◆ industrialización de la agricultura ecológica:
  • empresas de productos ecológicos adquiridas por multinacionales

pérdida de la proximidad

PH Howard, Int. J. of Sociology of Agriculture and Food 16, 13, 2009
Aspectos Sociales de la Agricultura Ecológica (cont.)

◆ entorno local? - producción ecológica en África con destino a Europa del Norte
  • grandes granjas ecológicas próximas a aeropuertos
    ▪ transporte por avión
    ▪ hasta 2009, la Asociación del Suelo del Reino Unido:
      - NO etiqueta ecológica
    ▪ en 2009: SÍ etiqueta ecológica
      - razón: mejora de condiciones de vida de agricultores en países en desarrollo (Soil Association backs down on organic air freight issue: http://www.foodnavigator.com/content/view/print/234283)
      - NO está claro que la población rural se beneficie de estos cultivos ecológicos (Paarlberg, Starved for Science: how biotechnology is being kept out of Africa. 2008)

◆ industrialización:
  • significativamente la proximidad entre productores y consumidores, como en la agricultura convencional