Gene flow and its impacts

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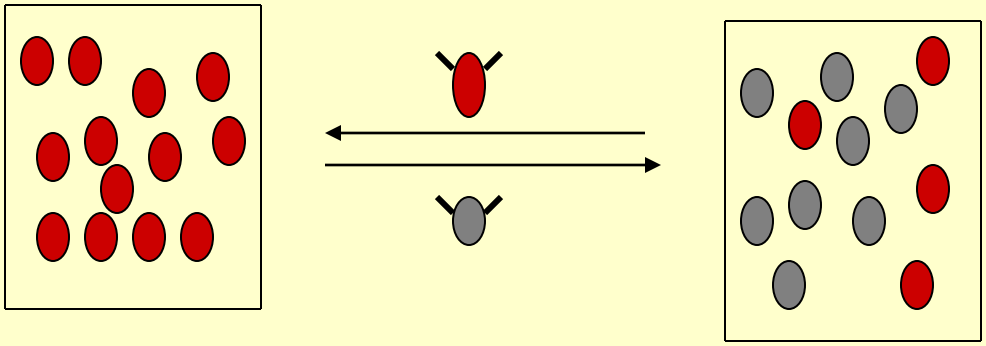
Topics to be covered:

- *What is gene flow?*
- *Where does gene flow occur?*
- *Factors influencing levels of gene flow.*
- *How do GM and traditionally bred (TB) crops differ.*
- *How can growers of GM and non-GM crops peacefully coexist?*

Focus on Africa

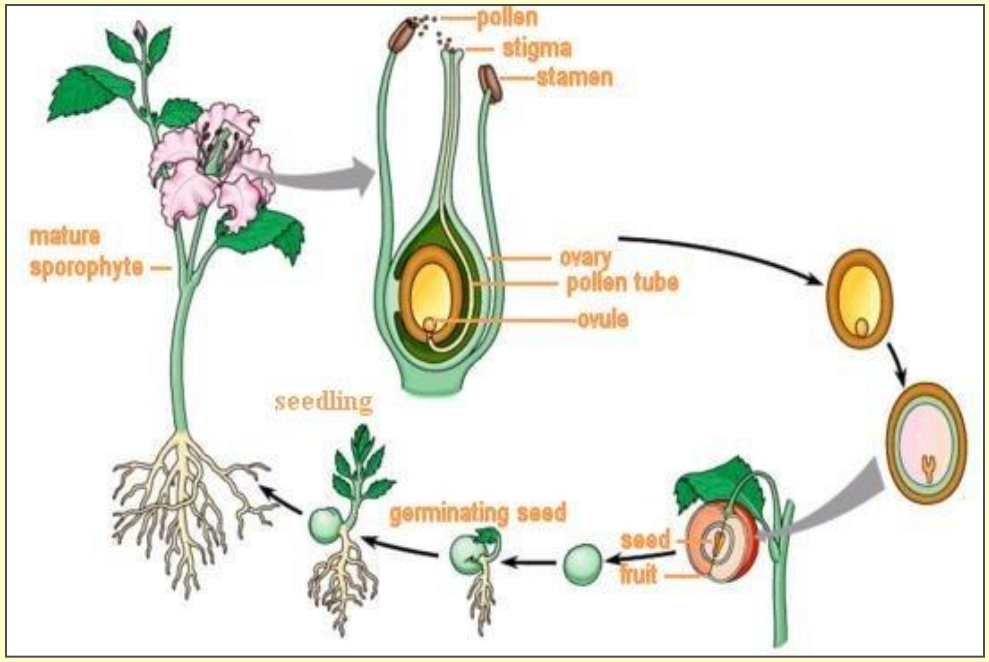
What is gene flow?



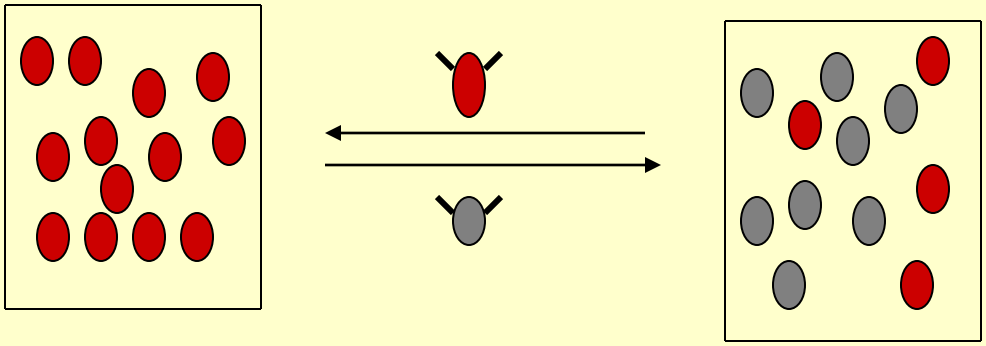
Movement of pollen and seeds between adjacent populations of relatives

Note!

Gene flow only has an impact if hybrids are produced that persist and reproduce!



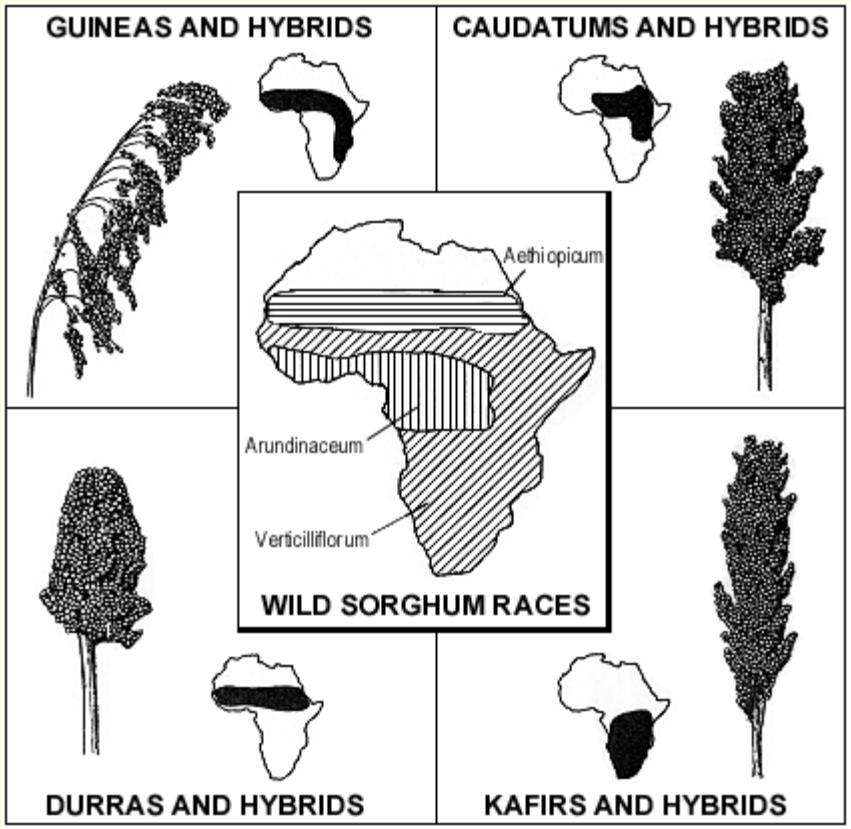
Where can gene flow occur?



Between wild relatives

Since the beginning of time

Wild sorghum types and their hybrids



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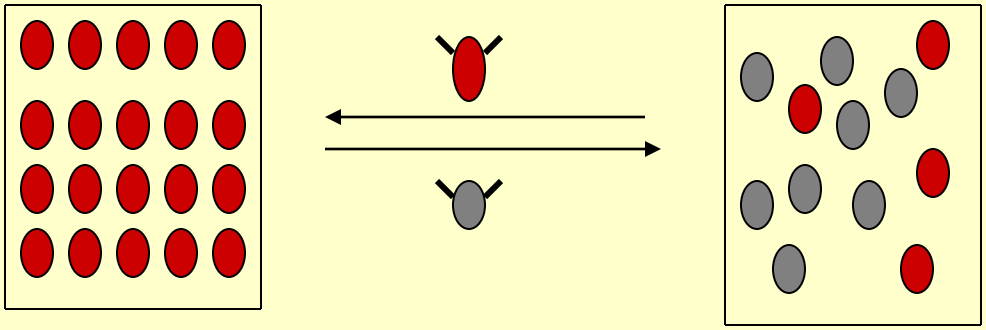
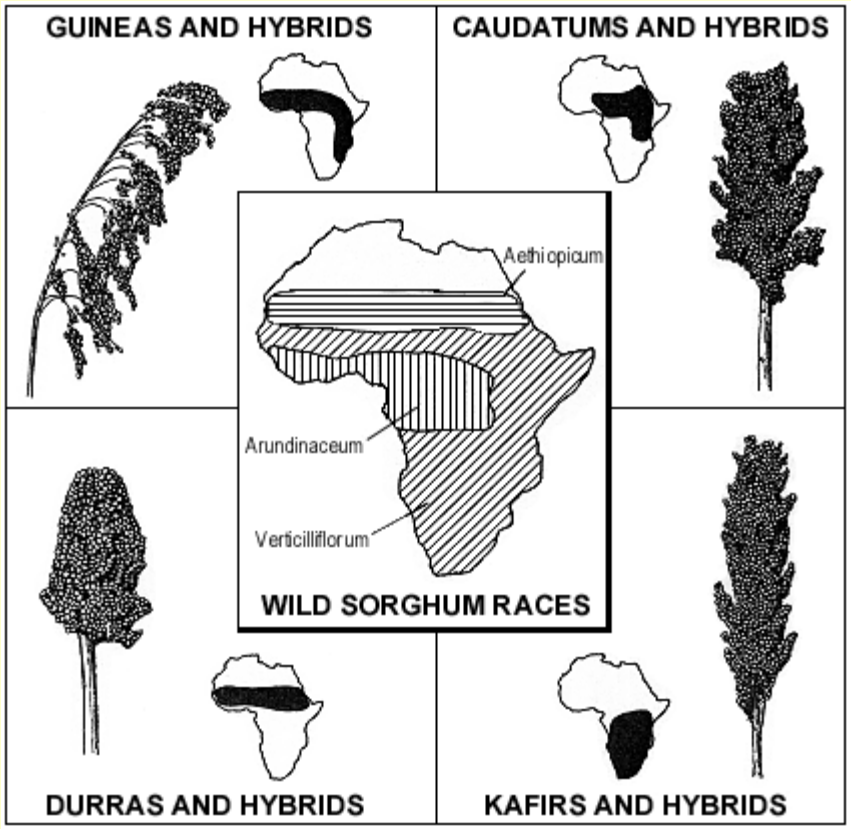


Between crops and wild relatives

For thousands of years

Wild sorghum types and their hybrids



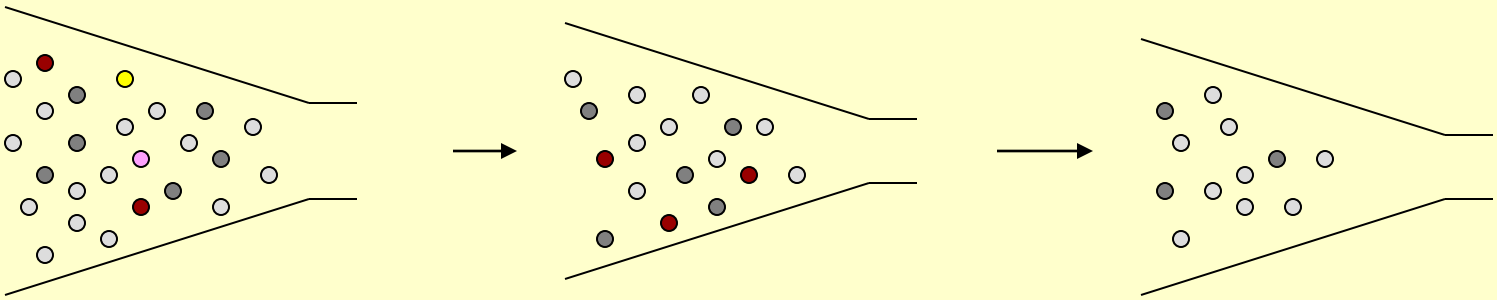
How does a crop variety differ from a wild species?

- *It has only a small sample of the genetic diversity found in its wild progenitors.*

- *It is the product of numerous rounds of hybridization and selection*

- *In general, they have lost their ability to be competitive in the wild*

Reduction in genetic diversity due to domestication



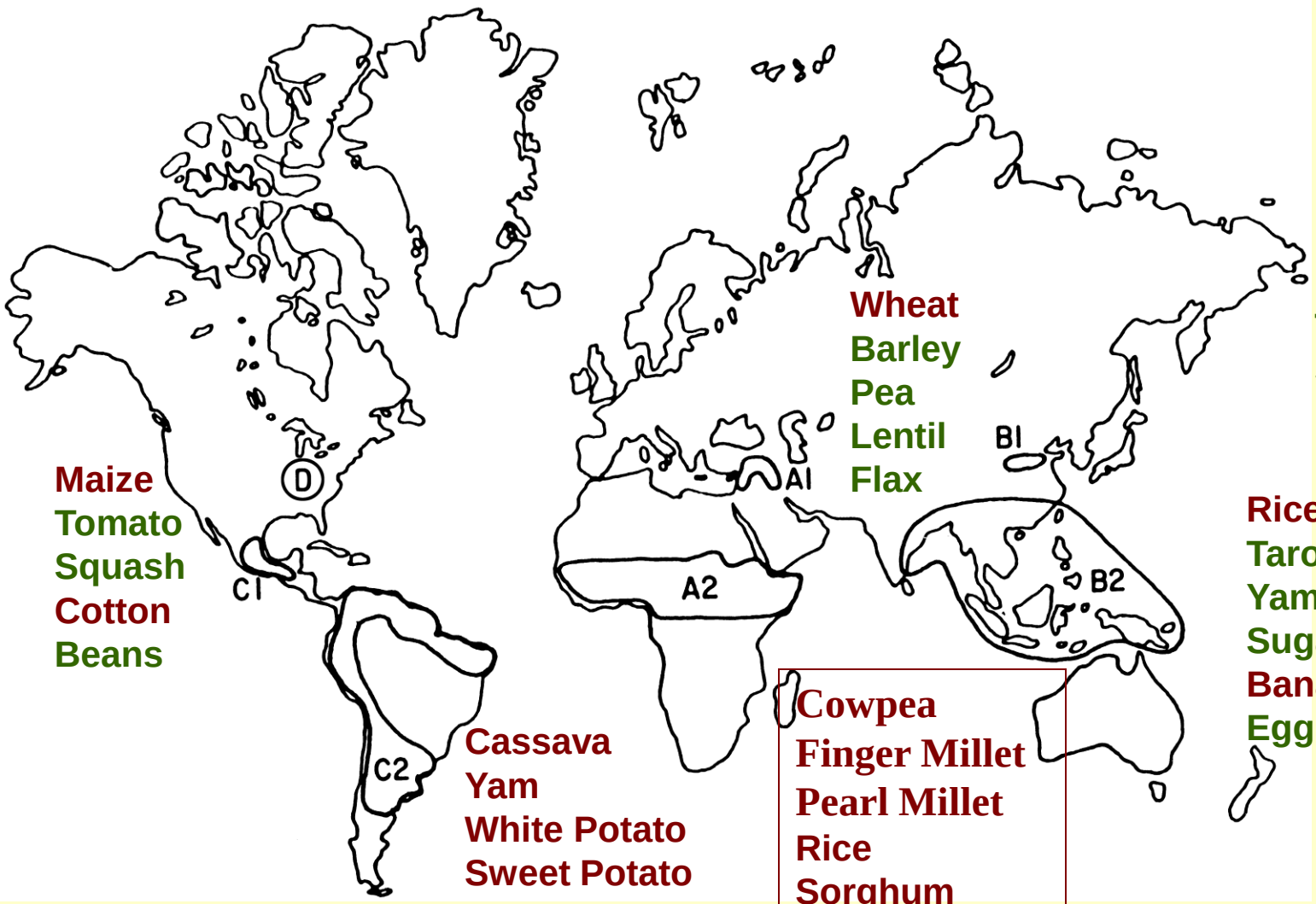
Wild species

Early domesticants and land races

Modern varieties

Redrawn from Tanksley, 1997

All crops have relatives somewhere:



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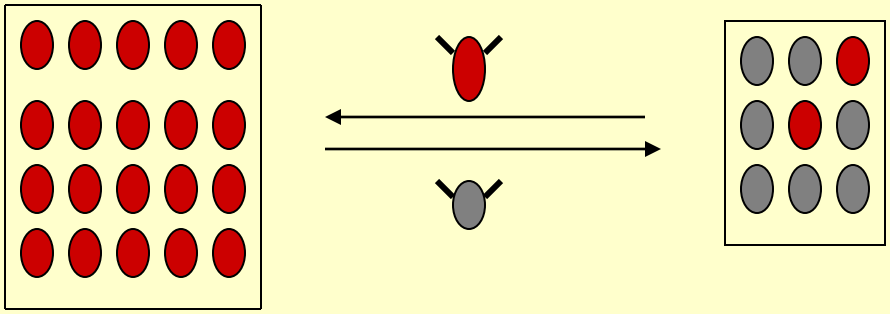

Between crops and land races

For a hundred years

What is a land race?

- ***Crop grown by traditional farmers***
- ***Represents an intermediate stage of domestication between a wild ancestor and a modern variety (bred by growers).***
- ***Can be very diverse across a geographical region***
- ***Is not static, can change over time, some farmers still "breed" them***

How is a land race different from a modern variety?

- ***Has unique traits the farmer desires***
- ***May be lower yielding but more dependable***
- ***Can carry higher levels of genetic diversity***

So, what African crops have wild relatives and land races?

African staple crops with close wild relatives:

Cowpea (E. and W. Africa)

Finger Millet (E. Africa)
Pearl Millet (W. Africa)

Sorghum (Most of Africa)

Yam (E. and W Africa)

African staple crops with distant wild relatives:

Rice
(West Africa)

Cotton
(Southern Africa)

Crop x wild hybrids are very rare

African staple crops without wild relatives

Banana
(SE Asia)

Cassava (S. America)

Maize (Mexico)

Sweet potato
(S. America)

So, in Africa

Pollen flow between crops and wild populations will not occur or is unlikely with:

Banana
Cassava
Maize
Sweet potato

Cotton
Rice

So, in Africa

Pollen flow between crops and wild populations will not occur or is unlikely with:

Banana
Cassava
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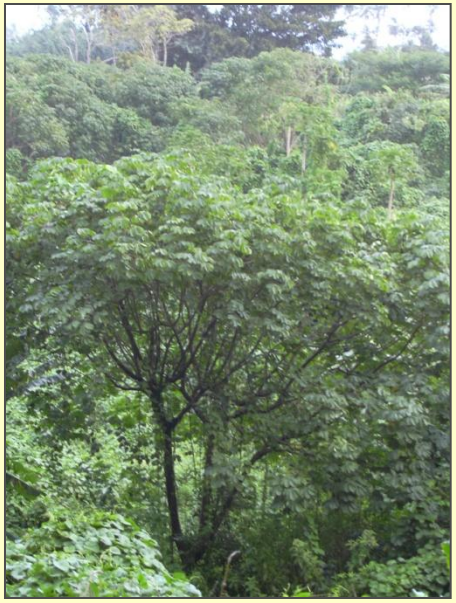
Sweet potato

Cotton
Rice



Cassava does have one compatible relative in Africa (*Manihot glaziovii)*
Ceara Rubber Tree.

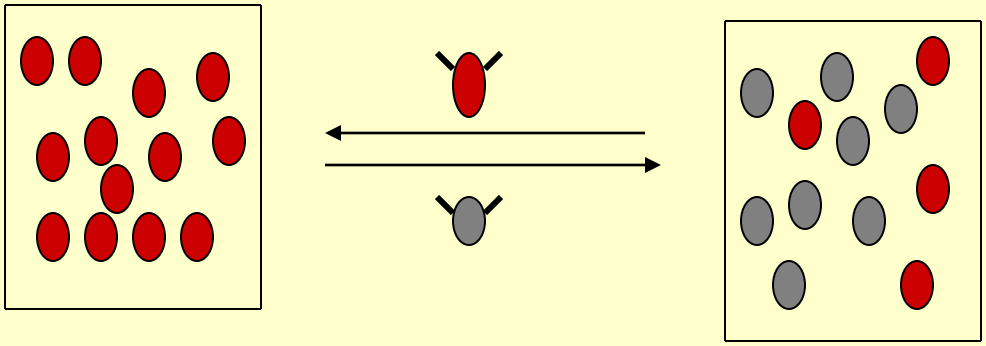
Introduced plantation crop

So, in Africa

Pollen flow between crops and wild relatives is possible with:

Cowpea in E. and W. Africa
Millets in E. and W. Africa
Sorghum across Africa
Yam in E. and W. Africa

So, how much gene flow occurs between inter-fertile crops, wild species and land races?



Depends on many factors.

The amount of pollen flow depends on:

- ✓ **The proximity of relatives**
- ✓ **Levels of inter-fertility**
  - **Just because two species are in the same genus doesn't mean they will readily hybridize (rice and cotton)**
- ✓ **The biology of the crop (crop characteristics)**

Some crops are even sterile themselves restricting gene flow.

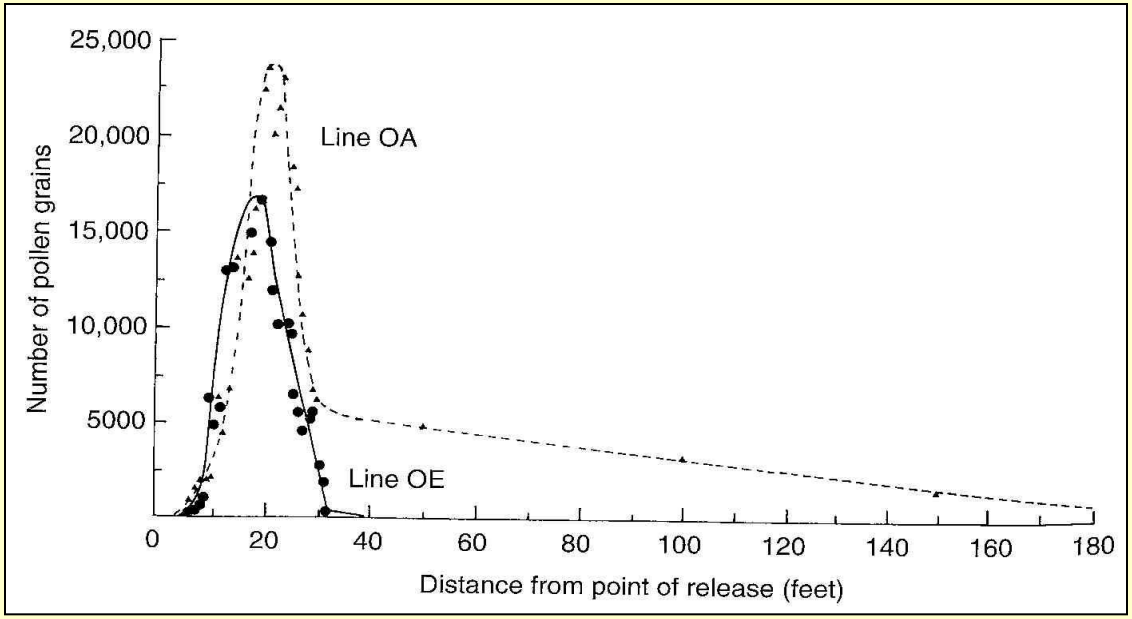
The cultivated banana is sterile.
Cassava, yam and sweet potato often don't flower and many varieties are sterile.

Farmers propagate these crops by cuttings

The amount of pollen flow depends on:

- ✓ **The proximity of relatives**
- ✓ **Levels of inter-fertility**
  - **Just because two species are in the same genus doesn't mean they will readily hybridize**
- ✓ **The biology of the crop (crop characteristics)**

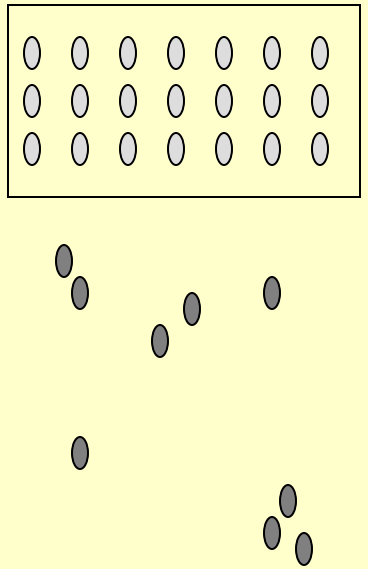
Most gene flow occurs over very short distances



But, individual crops differ in how far their pollen travels depending on their biology

Four crop characteristics determine levels of gene flow

- **Flowering time**
- **Breeding system**
  - **Selfing vs. outcrossing**
- **Agent of pollination**
  - **Wind vs. insect**
- **Type of seed dispersal**



Average distance crops with different breeding systems must be isolated to produce pure seed lines (Levin and Kerster, 1970)

Breeding system	Crops	Isolation distance (m)
Selfing	14	120
Mixed	16	165
Outcrossed	21	300

Selfers

Outcrossers

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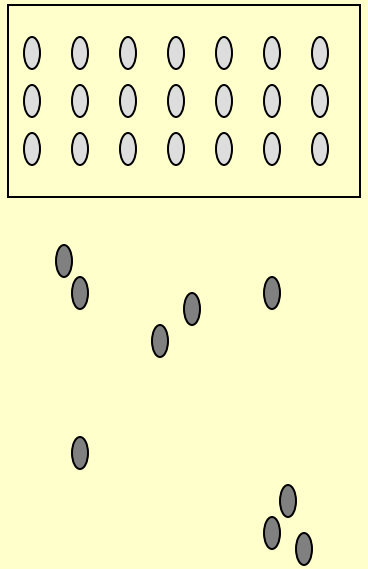


Average distance crops with different pollinators must be isolated to produce pure seed lines (Levin and Kerster, 1970)

Agent	Number	Isolation distance (m)
Wind	16	110
Insect	14	215

Insect

Wind

Crop biology of common African crops

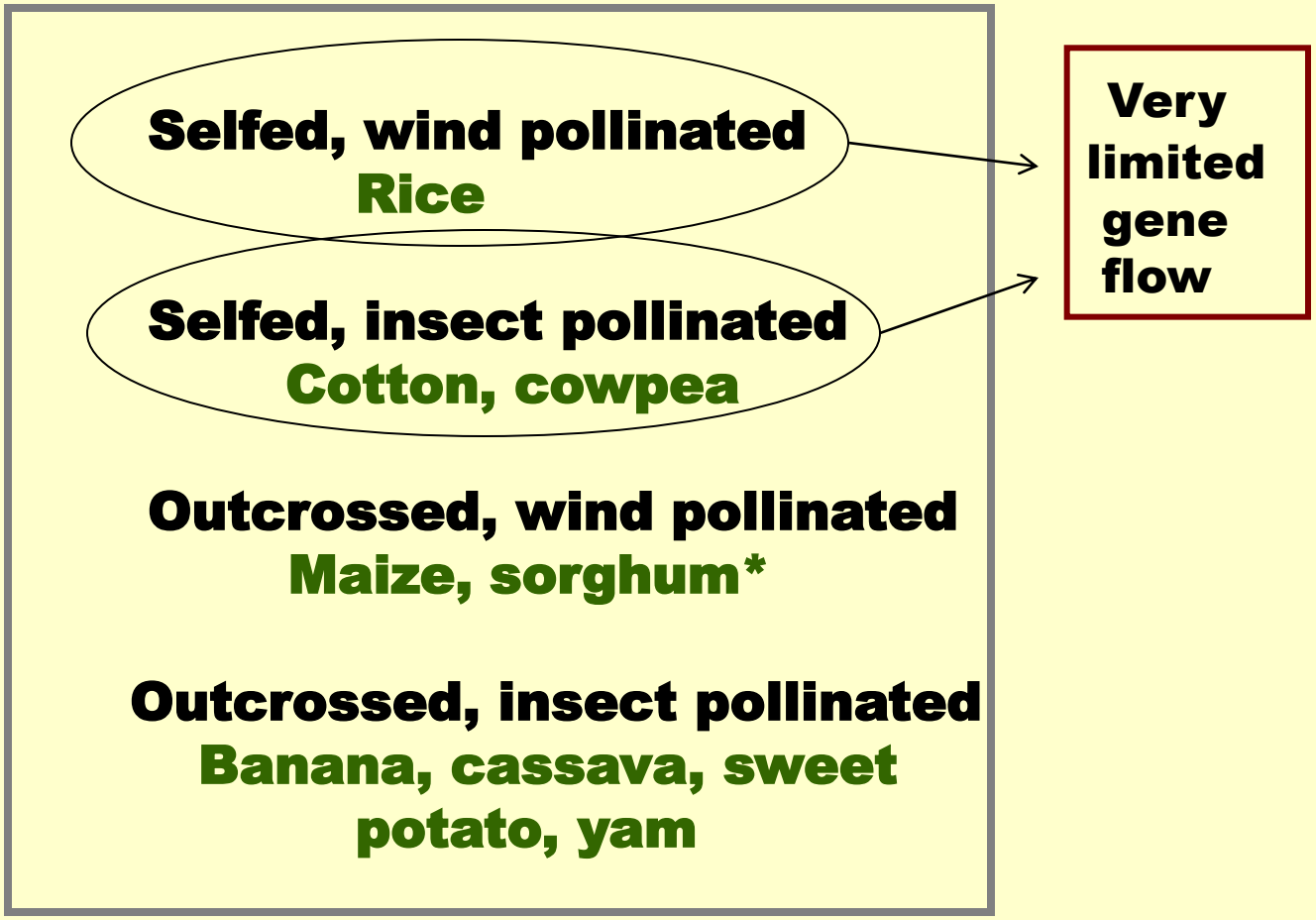
Selfed, wind pollinated
Rice

Selfed, insect pollinated
Cotton*, cowpea

Outcrossed, wind pollinated
Maize, sorghum*

Outcrossed, insect pollinated
Banana, cassava, sweet potato, yam

Crop biology of common African crops



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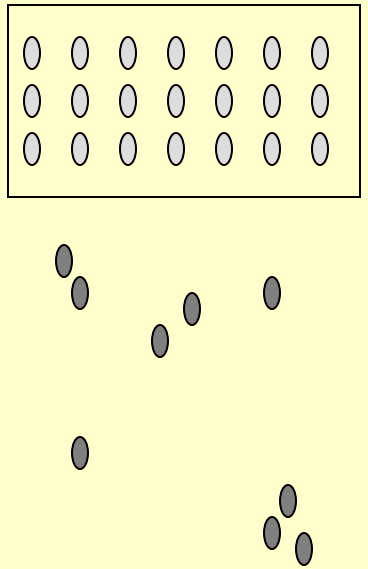


Mode of seed dispersal and the distance propagules travel (Levin and Kerster, 1970)

Type	Average distance
Gravity	< 1 m
Explosive	1 – 7 m
Wind	1 – 10 m
Animal	??

Gravity

Explosive

Wind

Animal

Minimum isolation distances recommended for registered seed production

Soybean – 0 m

Cowpea – 3 m

Rice – 3 m

Wheat – 15 m

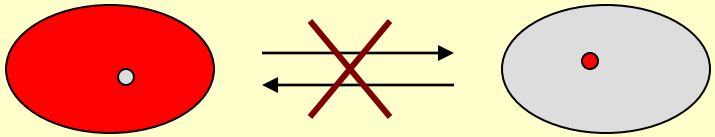
Cotton – 30 m

Cassava – 50 m

Maize – 200 m

Sorghum - 300 m

Millets – 300 to 500 m



< 1 %

Next question: How do GM crops differ in their patterns of pollen flow from traditionally bred (TB) crops?

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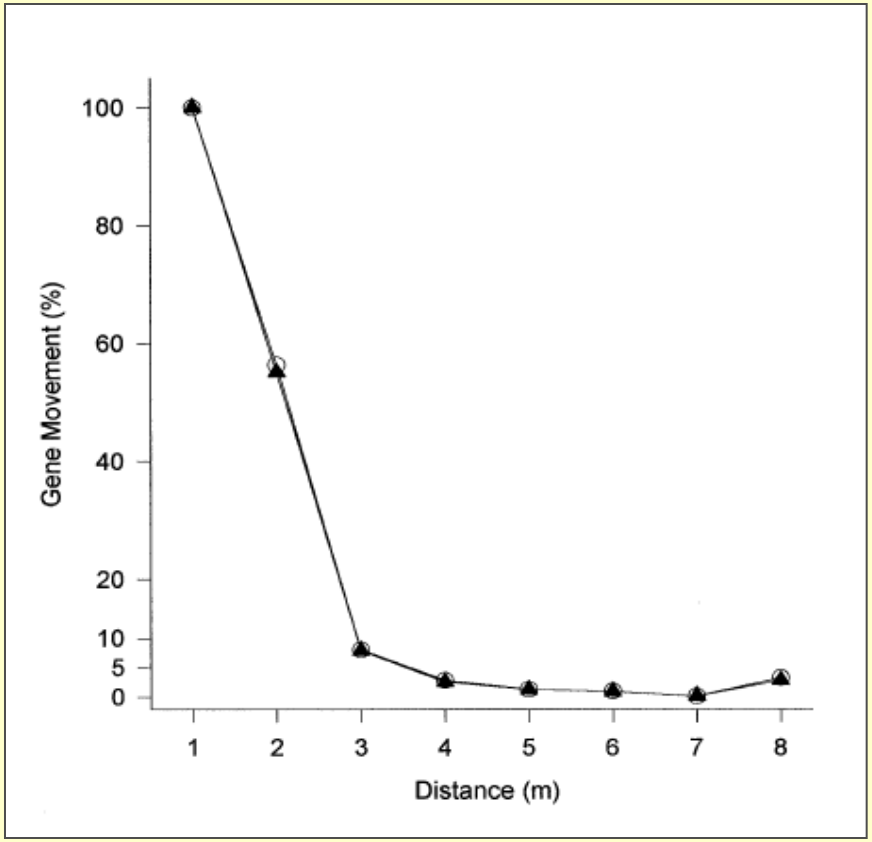
The answer is: They are exactly the same

The addition of a GM trait does not influence pollen flow.



A direct comparison of gene flow of native and engineered genes in melon. Hokanson, Hancock and Grumet. Euphytica 1997.

Extra traits added to GM crops

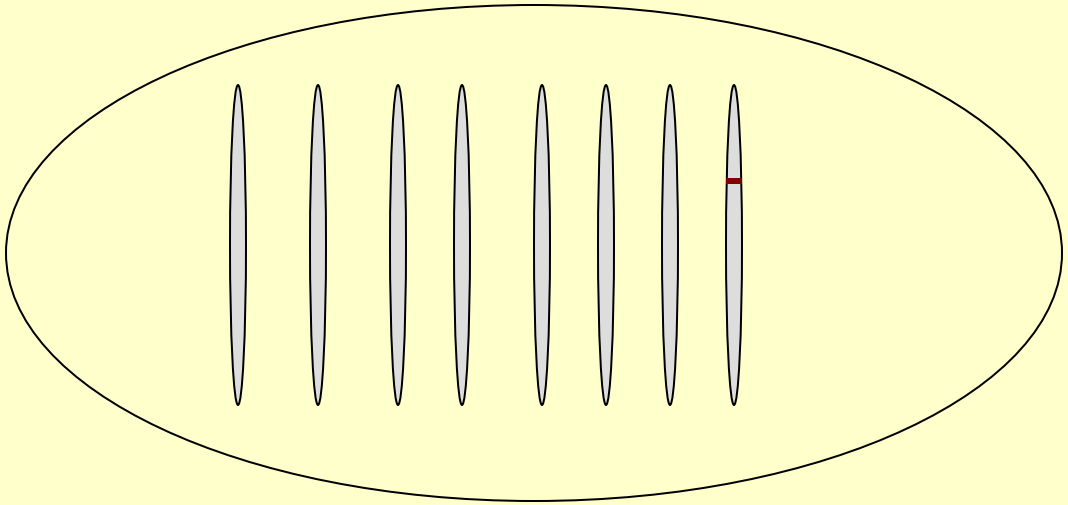
- *Virus resistance*
- *Insect resistance*
- *Herbicide resistance*
- *Nutritional attributes (biofortified)*
- *Drought tolerance*

The rest of the genetic makeup of the plant is unaltered

In genetic engineering, the gene (transgene) for a unique trait is inserted into a chromosome of a plant and then that plant is used to breed new varieties

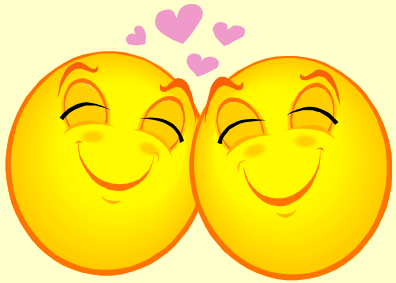
1 of ~20,000 genes

Nucleus of engineered plant

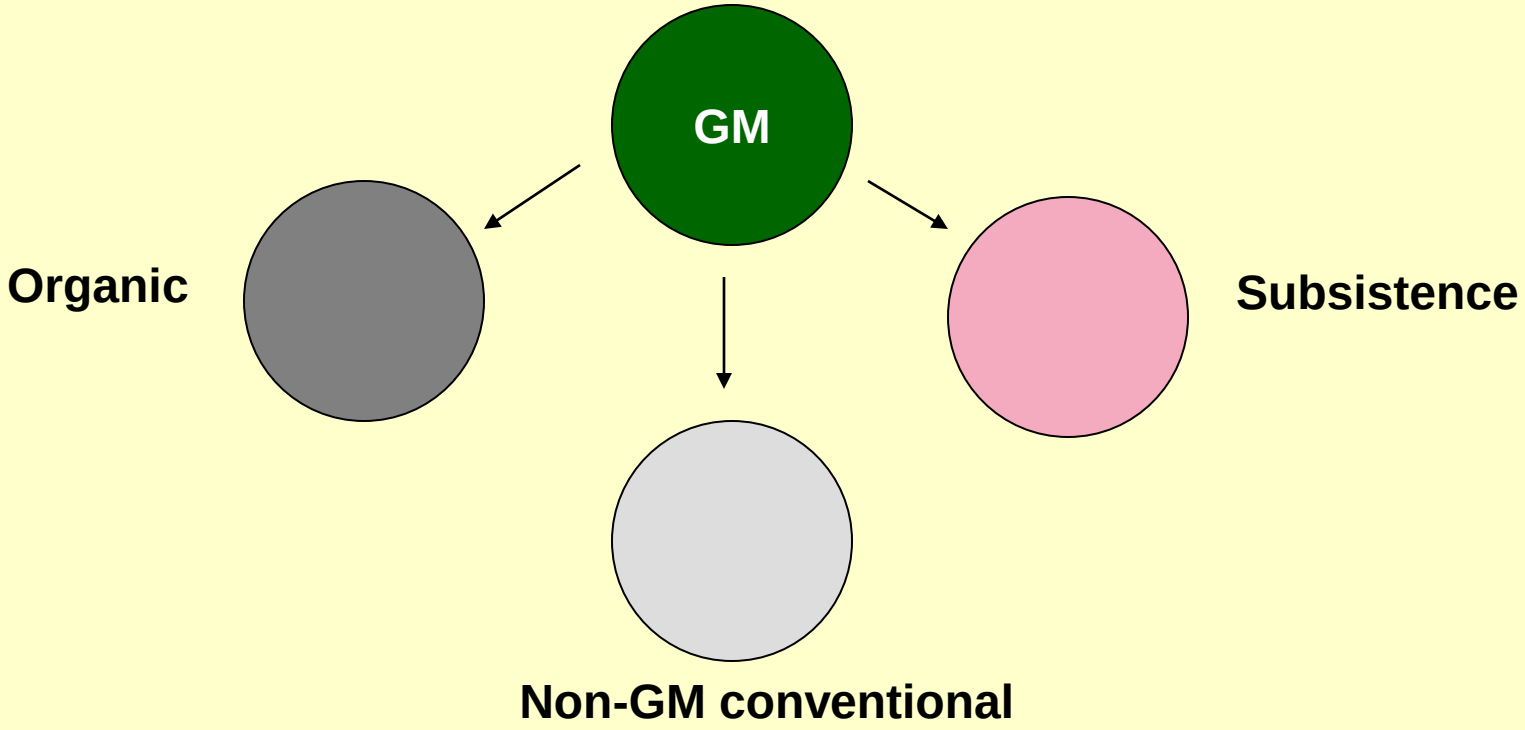


The question now becomes:

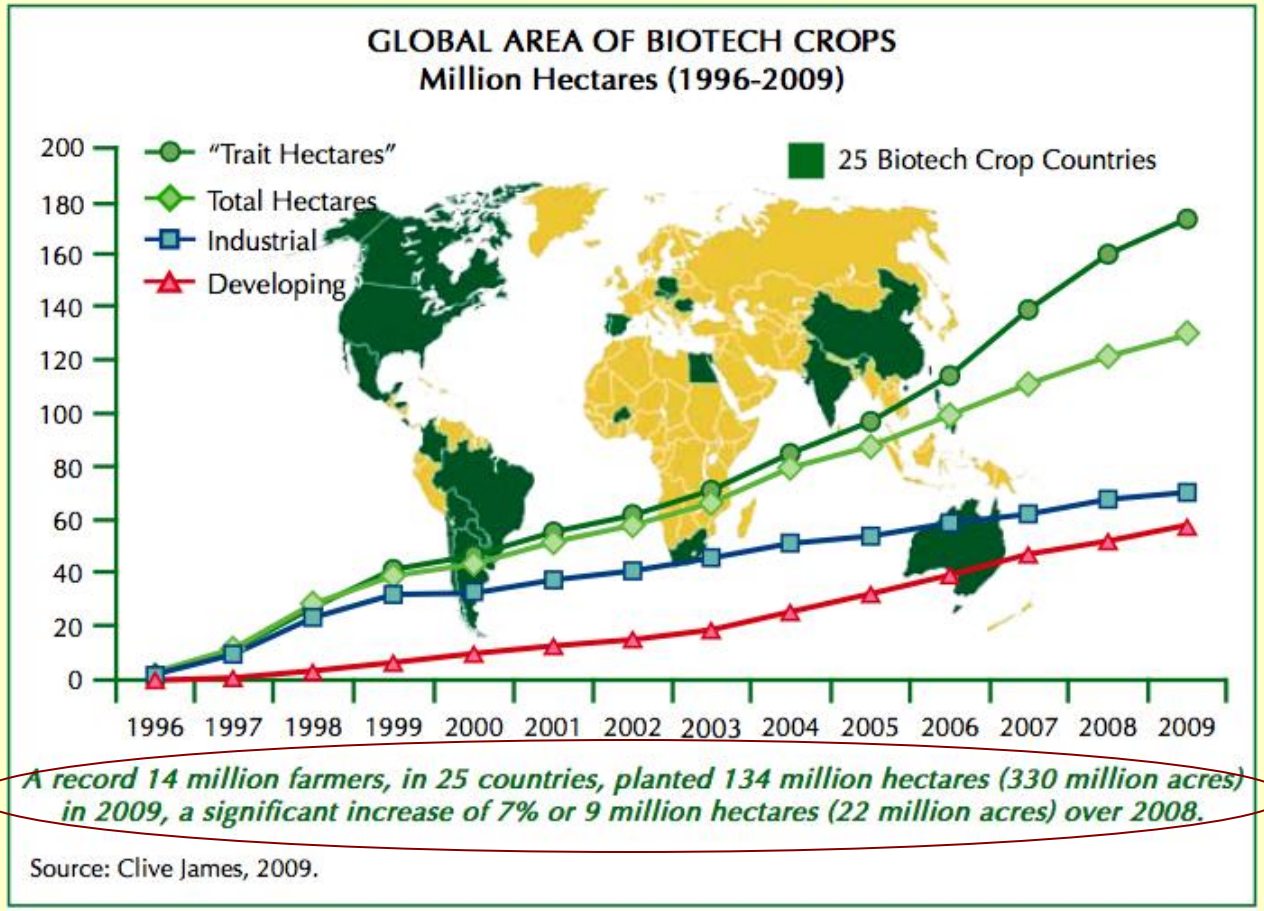
Whether growers of GM and non-GM crops can peacefully coexist?

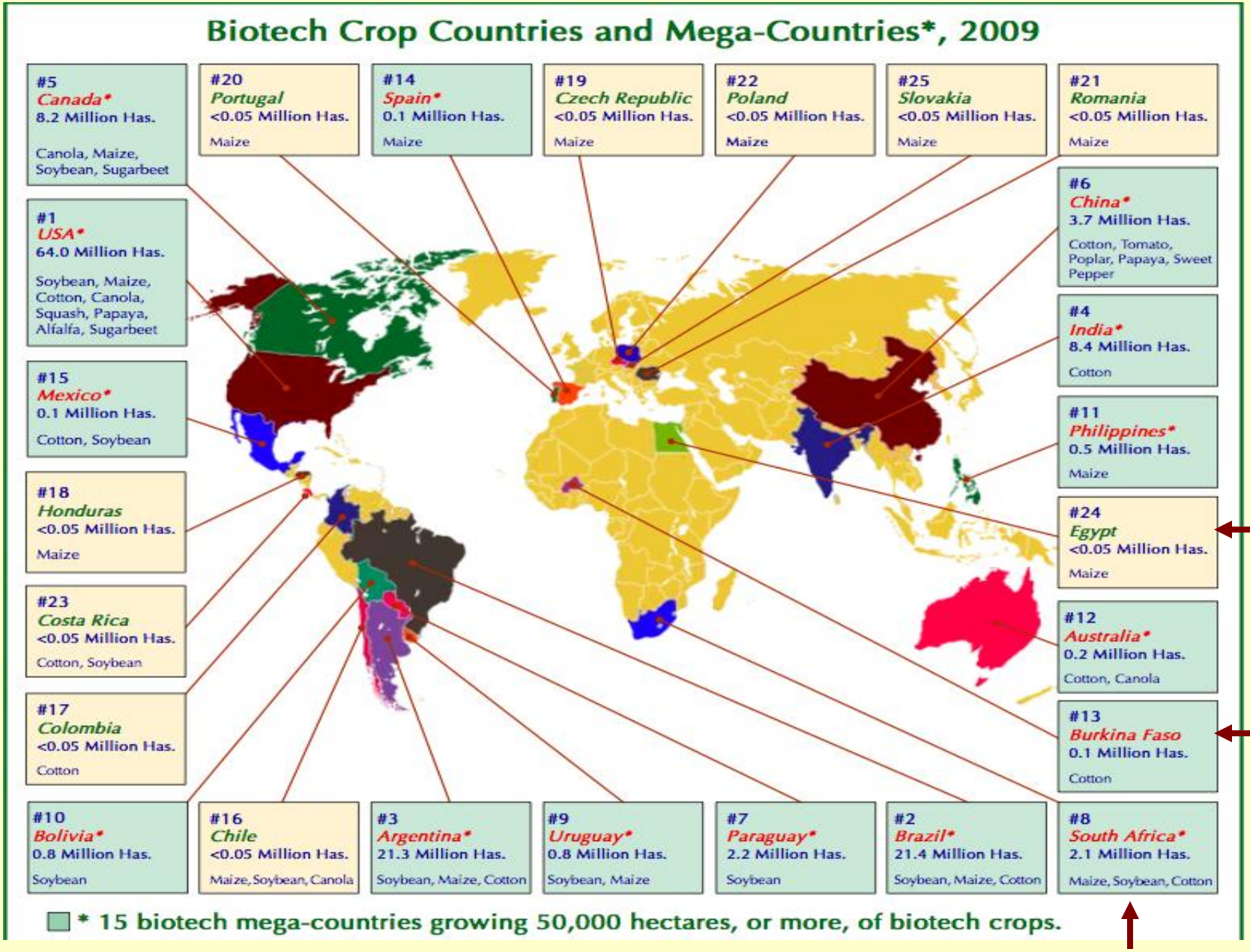


As GM acreage grows, so does the likelihood that engineered traits will find their way into non-GM crops



Adoption of GM technology has been swift across the world



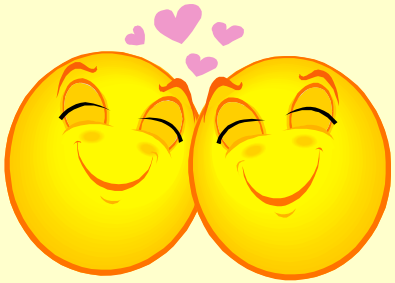

Biotech Crop Countries and Mega-Countries*, 2009
#5 Canada* 8.2 Million Has. Canola, Maize, Soybean, Sugarbeet
#20 Portugal <0.05 Million Has. Maize
#14 Spain* 0.1 Million Has. Maize
#19 Czech Republic <0.05 Million Has. Maize
#22 Poland <0.05 Million Has. Maize
#25 Slovakia <0.05 Million Has. Maize
#21 Romania <0.05 Million Has. Maize
#6 China* 3.7 Million Has. Cotton, Tomato, Poplar, Papaya, Sweet Pepper
#1 USA* 64.0 Million Has. Soybean, Maize, Cotton, Canola, Squash, Papaya, Alfalfa, Sugarbeet
#4 India* 8.4 Million Has. Cotton
#15 Mexico* 0.1 Million Has. Cotton, Soybean
#11 Philippines* 0.5 Million Has. Maize
#18 Honduras <0.05 Million Has. Maize
#24 Egypt <0.05 Million Has. Maize
#23 Costa Rica <0.05 Million Has. Cotton, Soybean
#12 Australia* 0.2 Million Has. Cotton, Canola
#17 Colombia <0.05 Million Has. Cotton
#13 Burkina Faso 0.1 Million Has. Cotton
#10 Bolivia* 0.8 Million Has. Soybean
#16 Chile <0.05 Million Has. Maize, Soybean, Canola
#3 Argentina* 21.3 Million Has. Soybean, Maize, Cotton
#9 Uruguay* 0.8 Million Has. Soybean, Maize
#7 Paraguay* 2.2 Million Has. Soybean
#2 Brazil* 21.4 Million Has. Soybean, Maize, Cotton
#8 South Africa* 2.1 Million Has. Maize, Soybean, Cotton
* 15 biotech mega-countries growing 50,000 hectares, or more, of biotech crops.

GM material finds its way into non-GM seed in two ways

1. *Physical mixing*
2. *Pollen drift*

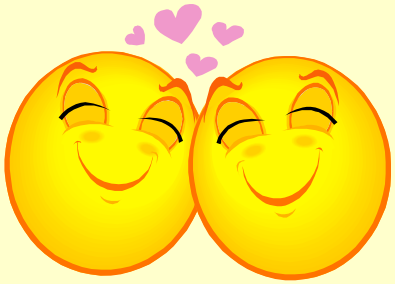
"Adventitious presence" – presence of GE material in a non-GM crop or product

So, can growers of GM and non-GM crops peacefully coexist ?



***Depends on the crop** – For some crops like like cowpea and cotton, gene flow **is so restricted** that it is unlikely to occur even between adjacent GM and non-GM fields.*

So, can growers of GM and non-GM crops peacefully coexist ?



For crops with more gene flow, the key will be to decide on what are acceptable threshold levels and then develop protocols to achieve these levels.

The most complete solution will be to totally prevent cross pollination .....

But these technologies are still experimental and often leaky.

Terminator technology

In many cases, rules have already been made on the adventitious presence of GM

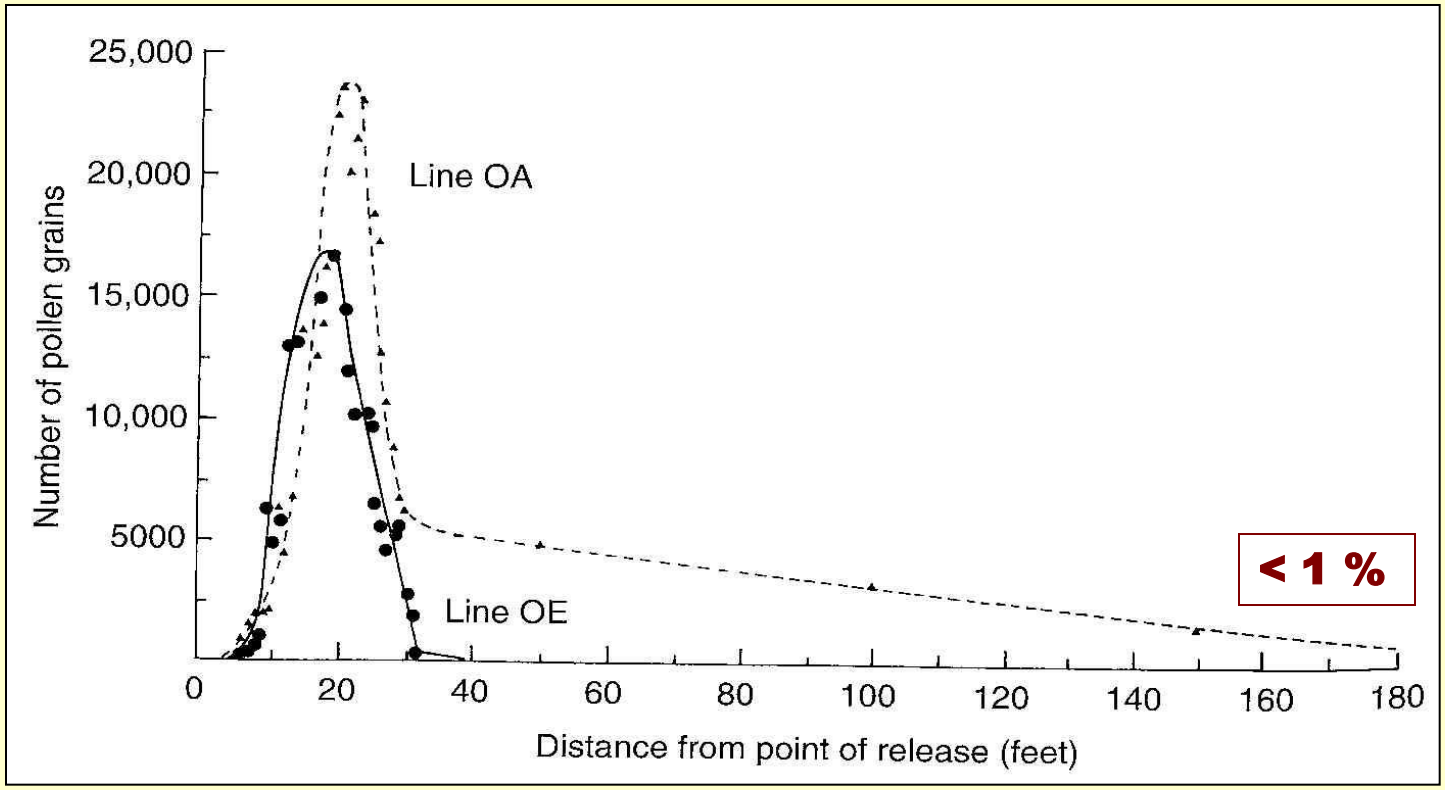
- *US : no threshold, no labeling*
- *EU : > 0.9% must be labeled*
- *Australia, New Zealand and Brazil : > 1 % must be labeled*
- *Japan : > 5% must be labeled*

Not safety based – market driven!

As far as physical mixing of seed is concerned

- *Farmers, seed suppliers and grain elevators operators must work together to keep seed segregated*

As far as pollen contamination is concerned, GM and non-GM crops must be sufficiently separated to keep pollen flow at the accepted level



AOSCA & OECD recommendations on isolation distance can be used to identify appropriate isolation distances

- *Certified – 2.0 %*
- *Registered – 1.0 %*
- *Foundation – 0.1 %*

AOSCA & OECD recommendations on isolation distance can be used to identify appropriate isolation distances

- *Certified – 2.0 %*
- *Registered – 1.0 %* ←
- *Foundation – 0.1 %*

Meets EU standard for adventitious presence

Minimum isolation distances recommended for registered seed production

Soybean – 0 m

Cowpea – 3 m

Rice – 3 m

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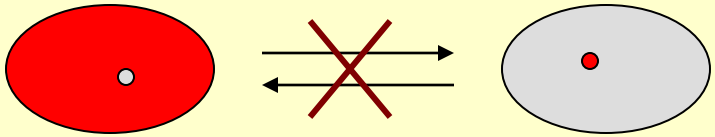
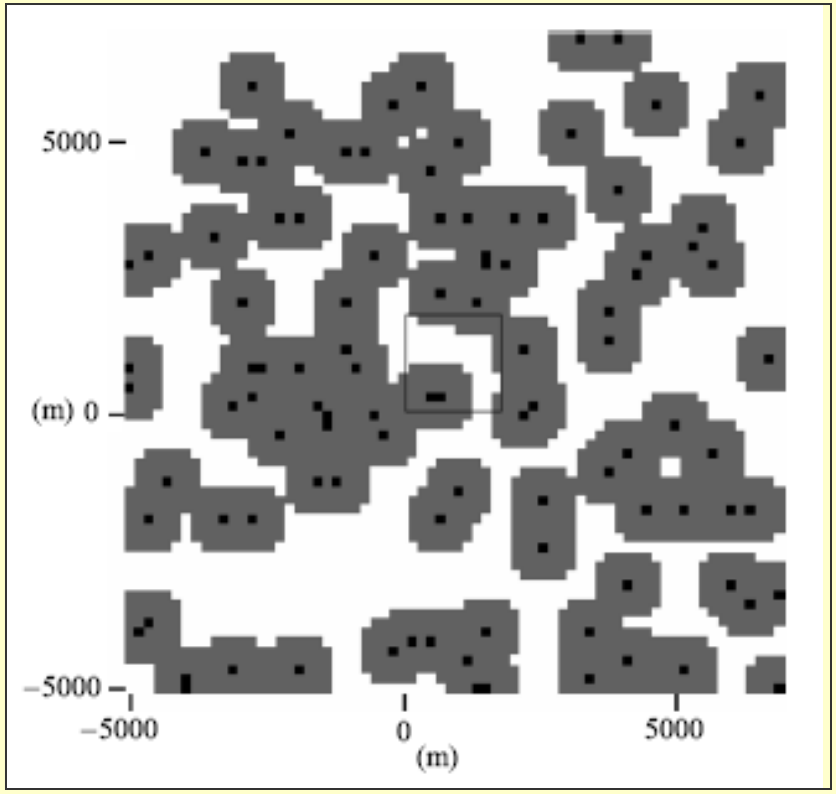


> 1 %

As GM crops become more common, finding appropriate separation distances will become more difficult with some crops



The major issues that will need to be resolved are:

- *Which crops have sufficient gene flow to worry about?*
- *Who is responsible for maintaining seed purity?*
  - *Do fields need to be "fenced in" or "fenced out"*
- *Should GM-free zones be established?*
- *Who should regulate?*

The European Commission just published general principles for developing national measures to avoid the unintended presence of GMOs in conventional and organic crops (June 22).

The recommendations allow flexibility for Member States to consider he particular local needs of conventional, organic and other types of crops.

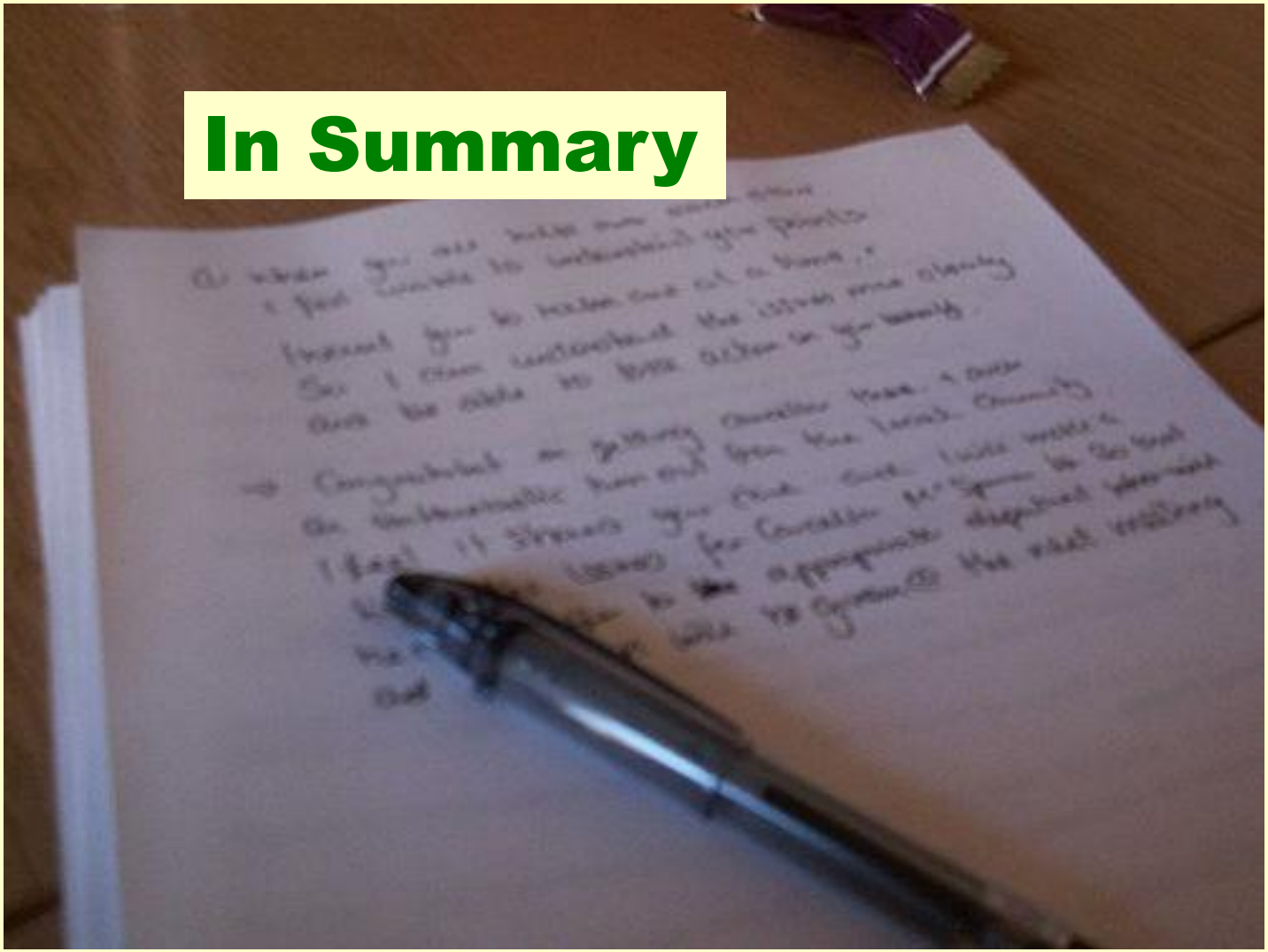
http://euroalert.net/en/news.aspx?idn=10126

What about subsistence farmers and land race purity?

- *The critical issue is whether GM crops are a different "threat" to land race purity than traditionally bred crops*

What about subsistence farmers and land race purity?

- *Traditionally bred (TB) crops have been grown for a hundred years*
- *The only difference between GM and TB crops is the added engineered trait*
- *Whether a engineered trait becomes incorporated into a land race is generally dependent on the farmer and how far he is from TB crops*


In Summary

Overall summary:

- ***Pollen flow can only occur where related species are in proximity***
  - ***For many African crops, pollen flow is not an issue as they do not have highly compatible, weedy relatives.***
    - ***Banana, cassava, maize, rice***

Overall summary:

- ***For many crops, pollen flow is also greatly restricted due to crop biology and low inter-fertility with relatives***
  - ***Limited by crop biology***
    - ***Cotton, cowpea, rice***
  - ***Often limited by self sterility***
    - ***Banana, cassava, yam, sweet potato***

Overall summary:

- ***The only difference between GM and traditionally bred crops is the engineered trait***
- ***The engineered traits do not themselves effect pollen flow***

Overall summary:

- ***For those crops where pollen flow could be an issue:***
  - ***If we are willing to set tolerance limits for adventitious presence, co-existence of all GM and non-GM crops can be accomplished!***

Merci!