Herbicide Resistant Crops: Gene Flow And Adventitious Presence

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Gene Flow and Adventitious Presence

- Gene flow is the change in gene frequency in a population due to movement of gametes, individuals, or groups of individuals from one place to another. (Slatkin 1986)
- Adventitious presence is the unintended presence of biotech material in an agricultural commodity.

Gene flow

- Can occur through pollen, seed, or vegetative propagules
- Can occur with nonresistant cultivars of the same species
- Can occur with weedy or wild relatives
- Is not unique to GE crops

Gene Flow

- Is often raised as one of the major issues surrounding the introduction of genetically modified (GE) crops
- Leads to adventitious presence of the transgene

Considerations for release of GE crops:

- outcrossing to nonGE crops
- outcrossing to related species
- control of the crop that escapes or volunteers – pollen source
- will weed problems increase

Should we be concerned??????????

- Possible answers
  - Yes
  - No
  - Maybe or Maybe Not
  - It Depends

Gene flow: Occurrence vs. Consequence

- Gene flow **will occur** but does it matter
  - human health
  - social
  - political
  - marketing
  - biological

Gene flow: Occurrence vs. Consequence

- Biological consequences
  - can be neutral – no advantage or disadvantage
  - can be positive – increase competitiveness or survival
  - can be negative – decrease competitiveness or survival

Biological consequences depend on:

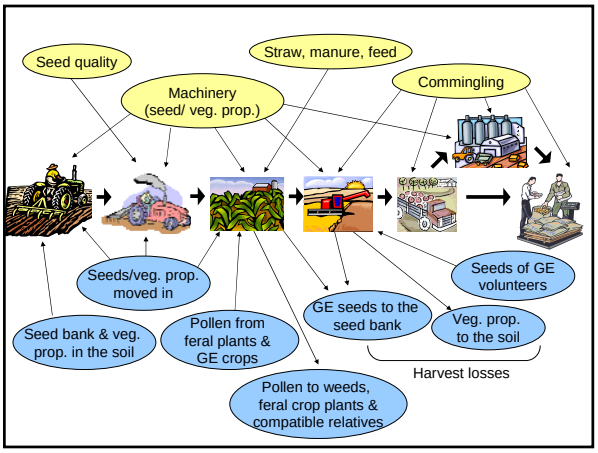
- the trait itself
- cross-fertility levels
- hybrid fitness
- selection pressure for the trait

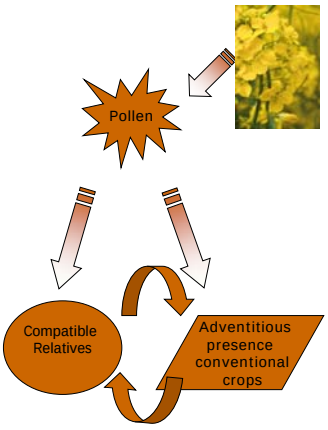
The questions are:

- will the trait present an advantage?
- will the gene be maintained or lost over subsequent generations?

Gene flow increases with:

- high outcrossing rates
- self-incompatibility
- wind pollination
- increased number of immigrants
- high seed dispersal; small seeds
- crops that persist outside of cultivated fields





Gene Flow - Pollen

- Requires:
  - compatibility between species
  - species must occur together
  - flowering periods must overlap

I don't have any hard evidence, Connie--but my intuition tells me that Ed's been cross-pollinating.

Pollen movement:

- most pollen falls close to mother plant
- tails of movement can be long and unknown
- pollen viability over distance and time is unknown

Gene flow via pollen can be reduced

- by spatial or temporal separation of compatible species
- by biological barriers such as male sterility
- by other technologies that are being developed

Gene Flow -Seed

- is a function of the system
  - volunteers in next crop
- leaky system – planting, harvesting, post harvest operations, end users
- must consider seed bank
- natural dispersal
  - wind, water, animals
- impossible to contain all seed
  - will plant become weedy

Gene flow via seed can be reduced

- by adding safeguards in the system
  - monitoring of each operation
  - cleaning equipment or dedicated equipment
  - produce crop in areas volunteers can be easily controlled
  - produce crop where there is no chance for admixture to occur

Gene flow from deregulated crops:

- Every crop is unique
- Can not make generalizations
- Studies have shown that there is adventitious presence of herbicide resistance transgenes in conventional crop seed supplies

Canola

- Insect and wind pollinated
- Many compatible weedy relatives
- Compatible crop relatives
- Feral populations

Corn

- Wind pollinated
  - separate space and time
- No compatible relatives
- Does not form feral populations

Alfalfa

- Insect pollinated
- Feral populations
- No weedy relatives

Sugarbeets

- Wind pollinated
- Compatible crops
- Isolated compatible weedy relatives

Non-deregulated crops

Wheat

- compatible weedy relative – jointed goatgrass
- low outcrossing

- Perennial grasses
  - most complicated

Crops known to outcross with wild or weedy relatives

- barley
- canola
- carrot
- cotton
- grasses
- oats
- pumpkins/ squash
- radish
- rice
- sorghum
- sunflower
- wheat
- and many others

Gene flow:

- accept that we cannot prevent pollen or seed movement
- accept that we cannot predict all outcomes of releasing GE crops
- focus on management and mitigation

Management issues:

- containment
  - "genetic trespass"
  - monitor gene movement
    - contamination of nonGE fields
    - movement outside of production fields
  - possible production districts
    - buffer zones

Management issues:

- control – volunteers and escapes
  - are there good alternatives
  - will alternatives cost more

Management issues:

- product end use
  - monitoring – who will be responsible
  - containment – how or will this be regulated
  - who will be responsible for the costs of gene flow

Gene Flow and Adventitious Presence

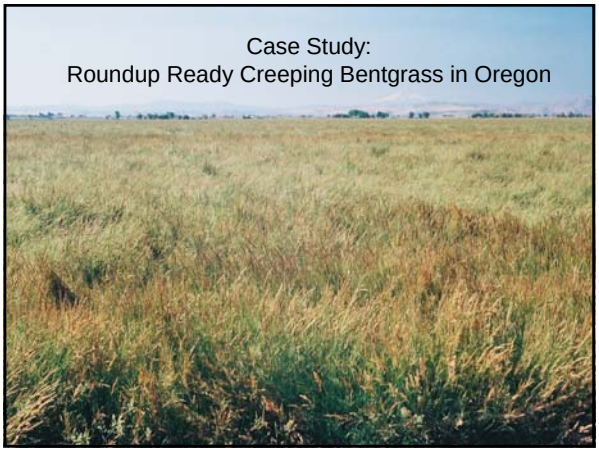
- Accept that can not prevent 100% of pollen or seed movement
- Zero tolerance levels can not be met; if required then the release of a GE crops is not possible
- Accept that we can not predict all outcomes of releasing GM crops
- Focus on defining consequence, management and mitigation

GE Crops and Gene Flow

- Must balance the risks and benefits
- Do the possible negative consequences outweigh the possible positive consequences?

Should we be concerned?????

- Yes
- No
- Maybe or Maybe Not
- It Depends



Creeping bentgrass (*Agrostis stolonifera*)

- outcrossing species
- self-incompatible
- wind pollinated
- perennial
- 5 million seed/lb
- many compatible relatives
- survives outside of cultivation

Background

- The development of GE Roundup Ready creeping bentgrass (*Agrostis stolonifera*) raised concerns among some members of the grass seed industry in the Willamette Valley of Oregon
- Desire by the company to produce seed for commercial sales even though still a regulated article

Concerns raised:

- Gene flow
  - pollen – to nonGE creeping bentgrass seed production fields or to weedy relatives
  - seed – movement to other production fields
  - stolons – movement out of fields
  - produce a Roundup resistant weed

Concerns raised:

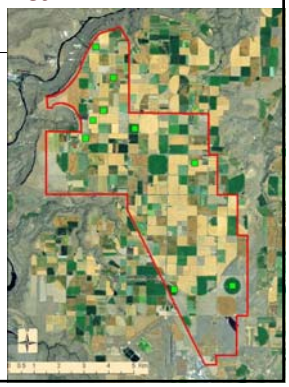
- Control options
  - alternatives to Roundup are more expensive
  - alternatives less effective
  - who pays for getting herbicides registered
- Contamination in other harvested crops
  - marketing issue
- Long term issue if not deregulated
  - too early in the process to plant large acreage

Bentgrass Control Area

- In response to concerns, a control area was established by the Oregon Department of Agriculture
- Separated from other creeping bentgrass production – in particular the Willamette Valley of Oregon

Production Control Area

- A 11,000 acre seed production control area near Madras, OR
- 400 acres planted with RR-creeping bentgrass in 2002
- Production practices strictly regulated



Bentgrass Control Area

- Safeguards to prevent pollen movement
  - bentgrass species were removed from all field borders, ditch banks, waterways, and roadsides within 900 feet of planted fields

Bentgrass Control Area

- Safeguards to prevent seed movement:
  - seed must be transported in sealed containers to and from fields
  - seed produced in the area must be cleaned and packaged in the area
  - equipment must be cleaned when leaving the field
  - dedicated combines that could not be used for other crops
  - straw must be burned or processed to devitalize any seed

Gene flow within the control area

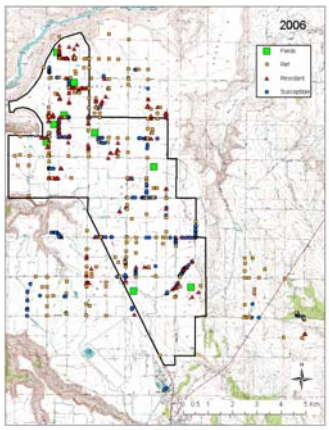
- In 2003 after swathing but before combining, a wind storm moved creeping bentgrass plant material including seed heads off some of the production fields
- Documented movement into other production fields within the control area
- Mitigation plan put in place
- Fields were removed from production

Survey results

- Surveys 2002 - 2006
- Walked canals and ditches and tested plants for herbicide resistance -Trait✓®
- Plants were geo-referenced
- Collected green tissue and panicles

Results 2006

- 1010 plants tested
- 354 or 35% resistant
- About 3 miles from closest field



Impacts of the gene flow

- Creeping bentgrass fields were removed from production
- GM creeping bentgrass plants were found in other crops in the control area
- Seed was quarantined
- Canals and irrigation ditches had to be sprayed to control the creeping bentgrass increasing herbicide use on these sites
- Clean up is ongoing

What we learned

- Concerns were well founded
- Still has not been deregulated 6 years later
- Even with safeguards in place, gene could not be contained
- Natural dispersal coupled with production practices led to increased movement
- Must have effective mitigation plan in place
- Must have control measures for all possible sites – e.g. canals, ditches, noncrop, crop

Questions for consideration

- Can one set of rules be used for all crops?
- Should isolation of GE crops be any different than those for non GE crops? Why or Why not?
- If so, when should they be different?