Protecting Your Non-GMO Grain From Contamination

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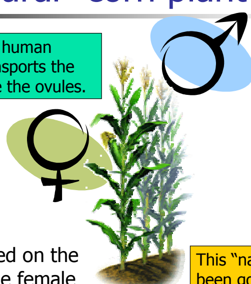
www.kingcorn.org
www.kingcorn.org/cafe
www.kingcorn.org/cafe/biotech.html

Genetic crop improvement…

- The "old-fashioned" way to achieve genetic crop improvement was through "natural" sexual acts among consenting, or sometimes not consenting, plants of the same species.

"Natural" corn plant sex…

Gravity, wind or human intervention transports the pollen to fertilize the ovules.



Pollen produced in the tassel anthers contains the male genetic material.

Ovules produced on the ears contain the female genetic material.

This "natural" sex has been going on for thousands of years!

Results of "natural" crop sex?

- Domestication of crops.
- Improved crop traits for enhanced yield and/or grain quality.
- Genetic modification (GM)
  - Rearrangement of genes within a species via natural or directed-pollination
  - Incorporation of genes from "wild" or "close" relatives via natural cross-pollination

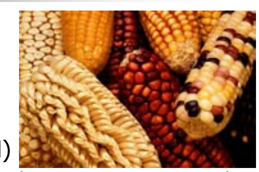
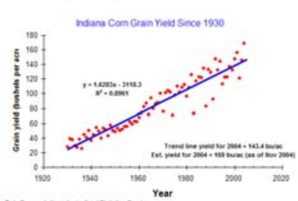


Image Source: USDA, Image Number K7743-13
http://www.ars.usda.gov/is/graphics/photos/

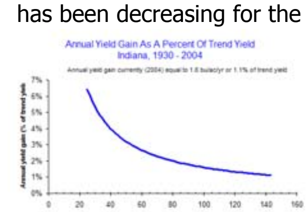
"Natural" GM of crops works!

- Indiana corn grain yields have increased by 1.6 bushels per acre per year for the last 70 years.
  - Primarily due to "natural" genetic modification (GM) and improved crop production technologies.



But, some worry…

- The annual yield gain (1.6 bu/ac/yr) as a percent of the yield potential of the corn crop has been decreasing for the past 70 years.



Nagging Question: Can we keep up with the increasing global need for food?

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Limits to crop breeding?

- Slow process to develop new varieties.
  - Not uncommon for 8 to 10 years from start to finish using traditional breeding techniques.
- Desired new or improved traits not always present in crop species.
  - Disease or insect resistance
  - Physiological improvements
  - Stress tolerance
  - Grain or plant composition

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Genetic Engineering

- Allows for faster variety development.
  - Tissue culture, recombinant DNA, etc.
- Allows for transferring heretofore unavailable genetic traits into a crop variety from unrelated species.
  - "Transgenic" ~~ TRANSfer of GENes

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Transgenic Example: Bt

- Bt genes originate from the soil bacteria, *Bacillus thuringiensis.*
- Researchers identified and isolated gene.
  - Literally "blasted" gene into corn DNA using gold particle gene guns.
  - Bt genes that successfully incorporated into corn DNA express the insecticidal Bt protein in corn plant grown by farmer.

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Gene transfer techniques…

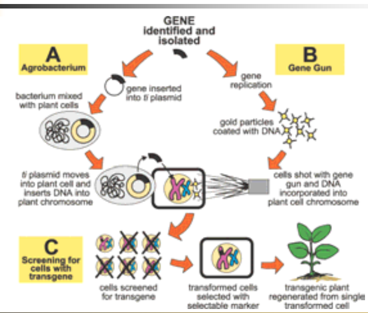

Image source: http://www.ext.nodak.edu/extpubs/plantsci/crops/a1219-2.gif

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Genes vs. Events

- Different versions of a gene often encode for the same general genetic trait (e.g, Bt proteins in corn).
  - The "Cry" class of insecticidal Bt proteins may be encoded for by several Bt genes: Cry1a(b), Cry1a(c), Cry9c, Cry3Bb1, etc.
- Therefore, some Bt hybrids differ because they employ different versions of the Bt gene.

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Remember StarLink™?

StarLink Insect Protection

- StarLink™ corn hybrids contained the Cry9C insecticidal gene.
  - Same mode of action as other Bt genes, but
  - The protein had different binding site in the insect gut than that from other Bt versions,
    - Unfortunately, was never approved for the human food chain.

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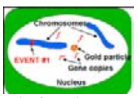
Genes vs. Events

- The combination of a specific gene and its chromosomal location within a crop's genome is termed an "event".
  - Two companies may use the same Bt gene, but located in different chromosomes; thus are termed different "events".



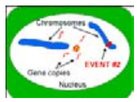


Image Source: Univ. of Nebraska http://www.agbiosafety.unl.edu/education/transformation.htm

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Example: Cry1Ab Bt gene

Event	Company
176	Syngenta
BT11	Syngenta
MON80100	Monsanto
MON802	Monsanto
MON809	Pioneer
MON810	Monsanto

Source: Univ. of Nebraska, http://agbiosafety.unl.edu/

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Non-approved hybrids…

- Some transgenic traits are not yet approved for global marketing, primarily the European Union.
  - Herculex™ I (TC1507) - Bt CB (Cornborer)
  - Roundup Ready™ (GA21) – Glyphosate tolerance
    - Including stacks w/ other transgenics
  - Roundup Ready™ (Nk603) stacks w/ other transgenics
    - NK603 approved as individual trait 10/26/04
  - YieldGard (MON810) + Liberty Link™ (T25) stack
  - YieldGard™ (MON863) - Bt Corn rootworm (RW)
  - YG Plus™ (MON810 + MON863) - Bt CB +RW

Information current as of 11/12/04
Sources: National Corn Growers Assoc & European Commission Press Releases

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Some grain buyers…

- Will not accept grain from these non-approved hybrids nor grain contaminated with non-approved GMO traits.
  - Especially wet millers that export gluten feed by-product to Europe.
  - Tolerance levels are very low and in some cases is ZERO (0) percent contamination.

Image source: Corn Refiners Association http://www.corn.org/web/feed.htm

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Some growers…

- Have opportunities to market non-GMO grain for a premium.
  - Requires some quality assurance that grain is GMO-free.
  - May require formal certification protocol.

Image source: http://www.usda.gov/oc/photo/94cs3921.htm

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Some organic growers…

- Worry about losing their organic certification if GMO contamination is detected in their grain.
- Worry about being liable to company lawsuits if patented transgenes are detected in their self-produced open-pollinated corn varieties.

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Grain contamination: How?

- Genetically impure seed lots.
  - Seed companies face same challenges in producing GMO-free seed.
- Volunteer plants from previous GMO crop.
- Mechanical mixing of grain.
- Pollen drift from adjacent GMO fields.

Recognize that managing the risk of grain contamination is almost entirely on the shoulders of the producer.

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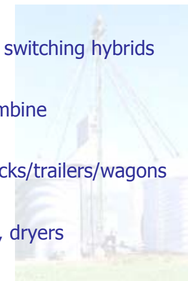
Mechanical mixing of grain…



- Planting operation
  - Seed in hoppers & meters when switching hybrids
- Harvest operation
  - Grain in nooks 'n crannies of combine
- Grain transport
  - Grain in nooks 'n crannies of trucks/trailers/wagons
- Grain drying/storage
  - Grain in dump pits, augers, bins, dryers

Image source: http://www.grainelevatorphotos.com/photos/ne/Dawson.html

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Equipment mgmt options…

- Plan field operations to prevent or minimize contamination during planting, harvesting, and handling.
- Implement a strict and thorough cleanout program for each piece of equipment that handles or processes seed or grain.
- Use dedicated equipment for planting, harvesting, and handling a particular crop.

Info from: Dirk Maier, Purdue.

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Field operation planning…

- Implementing a **First In Field – First Out of Field** (FIF – FOF) philosophy reduces the risk of mechanical contamination of non-GMO grain by GMO grain.
  - Plant & harvest non-GMO varieties first.
    - Any carryover seed in planter, combine, or transport from field will be non-GMO with little consequence to grain marketing.

Info from: Dirk Maier, Purdue, 2003.

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FIF – FOF in practice…

- Planting operation

  non-GMO hybrids 1st → GMO hybrids last
- Harvesting, drying, storage

  non-GMO hybrids 1st → GMO hybrids last
- Emptying storage, moving to market

  Cleanout equipment → non-GMO hybrids 1st → GMO hybrids last
  - Or eliminate cleanout at season end…

  GMO hybrids 1st → Cleanout equipment → non-GMO hybrids last

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Equipment hygiene…

- Is important for further minimizing the risk of mechanical contamination:
  - Run planter hoppers empty or vacuum out after planting GMO varieties, then thoroughly clean seed metering units.
  - Thoroughly clean out combines, grain transport vehicles, grain handling facilities, and grain storage facilities before start of harvest season to eliminate any carryover GMO grain from previous year.

Info from: Dirk Maier, Purdue, 2003.

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After handling GMO grain…

- "Flush" combines, grain handling equipment, wet holding bins, and dryers with 75 – 100 bu of non-GMO grain.
  - Will help "clean out" GMO grain from nooks 'n crannies of equipment.
  - "Flushed" grain must be considered contaminated, so should be "channeled" to buyers who accept GMOs.

Info from: Dirk Maier, Purdue.

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Pollen contamination risk…

- Is influenced by pollen viability and the potential for pollen drift to adjacent fields.
- **Pollen viability** decreases with increasing desiccation, which is influenced by…
  - Relative humidity
  - Temperature
  - Time after release
- **Pollen drift** is influenced by
  - Pollen settling rate
  - Wind
  - Physical barriers
  - Distance

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Pollen drift potential…

- Theoretically, corn pollen grains could travel nearly 1 mile in about 6 minutes with a 10 mph wind and remain viable enough to successfully pollinate an adjacent field of corn.
  - In reality, corn pollen settles at a rate of about 1 ft per second, so most of it won't travel far.
  - On a very calm day, **MOST** of a plant's pollen will likely land within feet of itself, not a quarter mile away.

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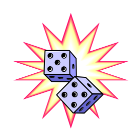
However, pollen will drift!

- Some pollen **WILL ALWAYS** drift from one corn field to an adjacent corn field.
- The only questions are…
  - How far?
  - How much?
  - When?



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Pollen drift research…

- Has tended to focus on seed production fields, not commercial hybrid fields.
  - Many studies have been conducted in geographic areas quite different from U.S. Midwest.
  - Data from Burris (2001) among the most applicable because of large number of test locations throughout the U.S. Midwest.

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Pollen drift reality…

- Actual severity of pollen drift to adjacent fields is fortunately quite low.
  - Between 1.5 and 2 % contamination in the first 100 ft of adjacent fields.
  - Decreases to about 1 % contamination beyond 100 ft, but still detectable at 600 ft.

Info source: Burris, 2001.

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Burris, 2001…

- Industry-wide study on factors associated with pollen intrusion (drift) into hybrid seed corn production fields.
  - Minnesota, Nebraska, Iowa, Illinois, Indiana
    - 1998 (60 fields)
    - 1999 (94 fields)
    - 2000 (212 fields)

Image source: Burris, 2001

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Field selection…

Pollen drift

- Fields selected for study were adjacent to known "contaminate" fields whose pollination timing coincided with that of the production field.
  - Contaminates were conventional, white, sweet, popcorn, or purple corn.

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Data collection…

Pollen drift

- Grain was sampled from female parent rows at varying distances from innermost border row of seed production fields and tested for contamination.
  - Electrophoresis testing performed for particular gene loci.

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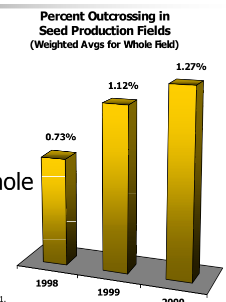
Outcrossing by year…

- Percent outcrossing (successful pollen drift) varied among years, primarily due to varying weather factors, but was detectable throughout whole fields.



Data source: Burris, 2001.

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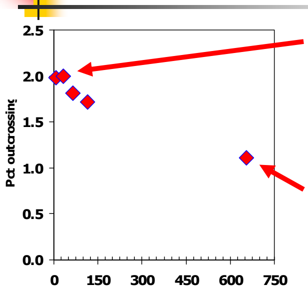
Outcrossing by distance…



- Percent outcrossing very low (2%) just beyond border rows of field.
- Decreased to approx. 1% contamination at 600+ ft into field.

Data source: Burris, 2001.

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Buffer row numbers…

- Interestingly, the number of buffer rows (from 6 to 24) had very little influence on the extent of outcrossing either near the buffer rows or farther out in the field.
  - May not translate directly to commercial hybrid production because buffer row number number in seed production fields tends to be confounded with pollen production characteristics of male parent.

Data source: Burris, 2001.

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One percent seems small…

- An outcrossing or contamination rate of 1% at a distance of over 600 ft from a pollen source sounds small, doesn't it?

- 1000 bu load of grain w/ 1% contamination:
  - Only ~ 10 bushels
- Detectable?
  - Depends on the luck of the draw (or probe).

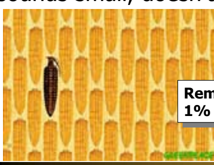

Image source: Greenpeace.org

Remember, some groups say even 1% contamination is unacceptable.

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Managing pollen drift…

- Is not always easy.
  - Corny condoms are available, but not feasible for use in whole field.
- Is never 100% certain.
- Requires good communication & sharing of records among neighboring farmers.
- Requires a firm understanding about the details of sex in the cornfield!

Image source: http://nmcserve.unl.edu/agro/Genetics/images/bagging-tassels2.jpg

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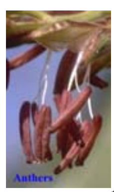
'Natural' sex in the cornfield…

Gravity, wind or human intervention transports the pollen to fertilize the ovules.

Pollen produced in the tassel anthers contains the male genetic material.



Ovules produced on the ears contain the female genetic material.

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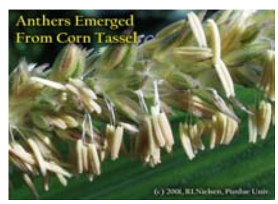
Male flowers of corn…



Estimates of total pollen production on single tassel range from 2 to 25 million pollen grains.

- Abt 6,000 total anthers
  - About 1000 spikelets per tassel.
  - Each spikelet contains two florets.
  - Each floret contains three anthers.
- Pollen is dispersed through pores that open at the tips of the anthers.

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Anthers & pollen shed…

- Anthers emerge first from middle of the central spike, then slowly from the remainder of tassel over about 7 days.
  - About 10 to 14 days for an entire field to finish pollen shed.

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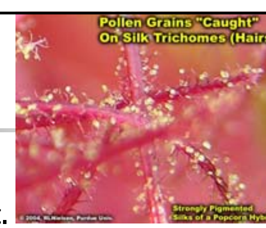
Corn pollen…



- Nearly microscopic, spherical, yellowish or whitish translucent.
- Daily pollen shed usually peaks by mid-morning, then tapers off.
- Once dispersed, pollen grains desiccate rapidly and become non-viable in only 1 to 2 hours.

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Female flowers of corn…

- Every ovule (potential kernel) develops a single silk (functional stigma of the female flower).
  - Approximately 1000 ovules develop per ear.
  - Usually 400 to 600 successfully develop into harvestable kernels.

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Silk emergence & receptivity

- Basal (butt-end) silks typically emerge first and apical (tip-end) silks last.
  - Silks are particularly receptive to pollen during first 3 to 5 days, then slowly deteriorate after that.
  - Silks continue to elongate until pollinated or deteriorated (about 8 to 10 days).

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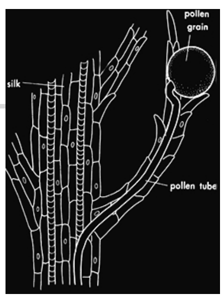
Pollen & silks…



- A pollen grain germinates within 30 minutes after landing on receptive silk,
- A pollen tube (containing male sperm cells) develops that penetrates the silk,
- Pollen tube elongates down to ovule within 24 hours where fertilization occurs w/ egg & endosperm.

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Pollen drift risk management

- Growers can attempt to manage the risk of pollen drift and its consequences by…
  - Heightened awareness & attention to details
  - Physical barriers to drift
  - Distance barriers to drift
  - Time barriers to drift.

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Pollen Drift Management:

Heightened awareness…

- Growers should visit with the folks farming fields adjacent to their fields.
  - Will non-approved GMOs be planted in fields adjacent to your non-GMO field?
  - Conversely, will you be planting non-approved GMOs that may affect neighbor's corn crop?

Image source: http://www.usda.gov/oc/photo/00di0909.htm

Obviously, assumes that neighbors are cooperative!

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Identify & document…

- Which fields will be planted to GMOs?
- What specific GMO event(s) will be planted?
  - Is it approved or non-approved?
- What are the intended and, eventually, actual planting date(s) of adjacent fields?
- What are the hybrid maturity ratings, especially heat units to silking?

Predict pollen shed dates…

- Based on planting dates and heat unit ratings to silking, you can estimate whether the timing of pollen shed in adjacent fields will overlap.

Pollen shed prediction…

- If planted same day, hybrid heat unit differences of 20 to 25 GDD equal about 1 calendar day difference in the onset of pollination.
- If planted different days, historical GDD accumulations can be used to predict calendar timing of the onset of pollination.

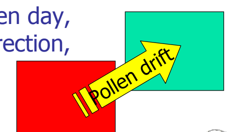
Historical heat unit accumulations for Indiana Crop Reporting Districts are available in Purdue's ID-179, Corn & Soybean Field Guide.

Pay attention to fields…

- Monitor your field(s) and neighboring fields as pollination time approaches to better determine risk of adjacent fields pollinating at the same time..
- Record the following dates for all fields:
  - 1st silks & tassels
  - 1st anthers/pollen
  - Last anthers/pollen
- Also note wind direction(s) during pollination.

Prevailing winds…

- Prevailing winds in Indiana typically from southwest to northeast in summer.
  - Pollen drift, therefore, expected to be greater risk from fields southwest of your fields.
  - But, of course on any given day, wind may be from any direction, so take notes daily!



Pollen Drift Management:

Physical barriers…

- Isolate transgenic or non-transgenic fields by planting adjacent to woodlots to create physical barriers to pollen drift.

Pollen Drift Management:

Distance barriers…

- Isolate transgenic or non-transgenic field by planting adjacent to non-corn fields or non-ag land to create distance barriers.

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Distance barriers…

- Seed industry standard for isolation distance to assure no greater than 0.5 % off-type seed in certified hybrid seed corn production is 660 feet from contaminate source.
    - Note that the goal is not zero (0) off-types (i.e., contamination), but rather no greater than 0.5 % contamination.

Info source: Association of Official Seed Certifying Agencies Genetic & Crop Standards, http://aosca.org/

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Distance barriers…

- USDA-APHIS proposed standard for field-testing of pharmaceutical corn crops…
    - No corn grown within one (1) mile of the field test site throughout the duration of any field test which involves uncontrolled corn pollination.

Image source: http://www.ucsusa.org

Info source: US Federal Register, Vol 68, No 46, 10 March 2003

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Border rows…

- Remember, rows bordering an adjacent GMO corn field will likely be most contaminated.
    - Harvest grain from first 16 to 32 rows separately from the rest of the field and market separately.
        - Feed on-farm, or
        - Market to buyers who accept transgenic grain

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Border rows…

- Recognize that remainder of field may still be contaminated at very low, but possibly detectable, background levels.
- If adjacent fields pollinated at different times than your field, handling the border rows separately may not be necessary due to low contamination risk.

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Two birds with one stone…

- Insect Resistance Management (IRM), mandated by US-EPA, requires Bt corn growers to plant a minimum of 20% of their acres to non-Bt hybrids to minimize risk of insect resistance to the Bt trait.
- Consider coupling IRM acreage requirements for Bt hybrids with distance barrier concepts to manage pollen drift.

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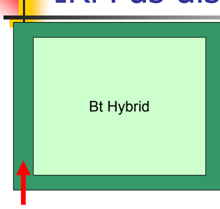
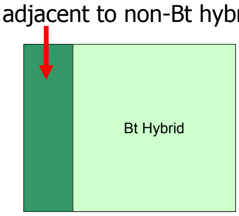
IRM as distance barrier…



- Non-Bt hybrid planted along edge of field adjacent to non-Bt hybrid.



- Non-Bt hybrid planted around field perimeter.

Remember that the IRM acres represent contaminated grain and should be channeled to appropriate markets.

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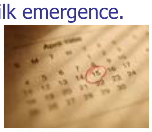
Pollen Drift Management:

Time barriers…

- Pollination timing of adjacent fields can be manipulated by:
  - Choice of hybrid maturity, especially in terms of heat units to silk emergence.



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Time barriers…

- Pollination timing of adjacent fields can also be manipulated by:
  - Choice of planting date
    - Every day difference in planting ~ 2/3 day difference in silking for same hybrid maturity.
    - Hybrid heat unit differences of 20 - 25 GDD equal about 1 calendar day difference.

Logistics of these strategies obviously complicated.

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When grain is contaminated…

- Consult the online ASTA Grain Handler's Database to locate grain handling facilities that will purchase, receive, and handle non-approved GMO grain in your area.
  - http://asta.farmprogress.com/
    - Hosted by the American Seed Trade Assoc.

asta first-the seed®
Grain Handler's Database

Image source: http://asta.farmprogress.com/

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References…

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