Pest Resistance Management of Genetically Engineered Crops

Dr. S.D. Suneth S. Sooriyapathirana

Senior Lecturer, Department of Molecular Biology and Biotechnology, Faculty of Science, University of Peradeniya

Resource Person, Plant Biotechnology Research and Outreach Center, Michigan State University

Goal: **Impart the knowledge on science of managing pest resistance against GE crops**

Objectives:

At the end of the session, participants will be able to

- **Explain the mechanism of developing pest resistance against GE crops**
- **Describe why pest resistance management is mandatory in GE crops**
- **Evaluate different options available for pest resistance management for GE crops**
- **Analyze the practical problems in implementing resistance management options**
- **Appreciate the pest resistance management as an essential tool for the sustainable use of GE crops**

Management of genetically engineered crops to maintain their effectiveness?

Concern about pest resistance

- **Pesticide resistance is a critical problem in agriculture**
- **Long history of control failures due to resistance against pesticides**
- **Need to consider resistance against GE crops**

- **Certain insect pests have developed resistance to nearly every insecticide used for their control**

Colorado potato beetle

Diamondback moth

Resistance to GE crops

- **Pests develop resistance to pesticides**
- **Process of natural selection**
- **Pests would develop mechanisms to survive in GE crops**
- **Resistance management in GE crops is mandatory**

Resistance

- **Resistance to pesticides**
- **Resistance to GE crops**
- **Host plant resistance**

  (GE pest resistant crops)

Pest resistance to GE crops

- **The <u>heritable</u> ability of a pest to withstand a genetically engineered crop that would <u>normally</u> be lethal**
  - **Not an acquired trait**
  - **(*e.g.* not like tolerance for caffeine or alcohol)**
- **A decrease in susceptibility that results in pest survival and damage, in a GE crop that would normally control the pest**
- **Not referring to a pest that was never controlled by the GE crop**

Management of pest resistance against GE crops is so important!

- **Only a few genes are available that can be used in a GE crop to control insect pests**

- **Once a pest becomes resistant, it will likely not change back to susceptible and the GE crop will likely <u>never</u> be effective again**

Pest resistance

- **Pests gain resistance to GE crops?**
  - **Pest resistance is an example of the evolution of an organism in response to selection pressure**
  - **Insects are tremendously adaptable to change and we should expect them to adapt to genetically engineered crops**

Pest resistance

- **Numbers game**
  - **Maybe only one pest in a million will carry a gene allowing survival in a GE crop**
  - **One hectare can host more than one million pests if there are 10 insects per plant**
  - **99.99% kill can leave 100 survivors**

Pest resistance

- **Resistance factors could come from?**
  - **Preexisting adaptation to toxins (** ***e.g.*** **plant defensive chemicals)**
  - **Preexisting adaptation to relaxed insecticides (** ***e.g.*** **Bt sprays)**
  - **Natural variability**
  - **Mutations**

Pest resistance

- **Strongest selection for resistance against a GE crop is possible when,**
  - **GE crop is grown repeatedly**
  - **No other mortality factors (no crop rotation, no biological control)**

Pest resistance

- **Lowest selection for resistance to a GE crop is possible when,**
  - **GE crop is grown rarely**
  - **Other mortality factors are implemented**

Pest resistance

- When a new GE variety is introduced, 80-90% of the crop may be planted with the GE variety
- Creates very strong selection for the pest
- Pest will adapt to the new GE crop

Options to manage pest resistance

- **Limit use of genetically engineered crop**
  - **Works if there are non-GE options that are good alternatives**
  - **But the GE varieties are often preferred**

Options to manage pest resistance

- **Different genes in different varieties**
  - **Genes need to be very different in the way pests might adapt to them**
  - **Sometimes different seed companies will have different genes**

Options to manage pest resistance

- **Two most commonly proposed methods**
  - **High dose/refuge strategy**
  - **Pyramid genes**

    (two resistance factors in the same plant)

High dose/refuge strategy

- **High dose – concentration of the toxin in the GE crop is very high**
  - **Perhaps 10,000 times or 20,000 times the amount needed to kill susceptible insects**
- **Refuge – There will be a portion of the crop planted to non-GE varieties, to produce large numbers of susceptible pests**

High dose/refuge strategy

- **Refuge for the pest**
  - **Alternate host crops**
  - **Wild hosts**
  - ***e.g.* if the GE crop is potato resistant to potato tuberworm, nearly tomatoes or eggplants can serve as the refuge**

High dose/refuge strategy

- **Assumptions**
  - **Genes in the pest allowing resistance to the GE crop will be recessive. Heterozygotes will ……………**
  - **The refuge will produce large numbers of susceptible pests that will mate with any resistant pest that may appear**
  - **Pests from refuge and GE crop will mix before mating**
  - **Offspring will then all be heterozygotes and will be susceptible to the GE crop**

High dose/refuge strategy

- **Assumptions**

Mating

RR = homozygous resistant from GE crop (very rare)

SS = homozygous susceptible from refuge (large numbers)

RS = heterozygous offspring are susceptible

High dose/refuge strategy

- **Difficulties**
  - Farmers do not want to plant non-GE varieties for refuges – may be a serious economic problem
  - Refuge may not produce large numbers of susceptible pests
  - Pests from refuge may not disperse and mate with pests from GEcrop

Pyramiding genes

Two resistance genes in the same plant

- **Theory**
  - **Two different resistance genes in the same plant will control pest resistant to either one**
- **Assumption**
  - **Individual pests can be resistant to only one gene**

Pyramiding genes

- **Difficulties**
  - **Two different genes are rarely available in the same GE crop**
  - **Genes have to be two widely different**
    - **Bt genes or one Bt gene plus another resistance gene or naturally-bred resistance factor**

Potential of pyramiding genes

- **Was very effective in greenhouse study with transgenic broccoli and diamondback moth (Zhao et al. 2005)**

- **However, having single gene varieties also in the cage negated the effectiveness of pyramiding genes**

Potential of pyramiding genes

Diamondback moth greenhouse study

Zhao et al. 2005

- **Host broccoli – four varieties**
  - **Susceptible**
  - ***Cry1Ac* GE plants**
  - ***Cry1C* GE plants**
  - **2-gene plants (Cry1Ac + Cry 1C)**
- **Pest diamondback moth – three strains**
  - **Susceptible**
  - **Cry1Ac - resistant**
  - **Cry1C - resistant**

Cry1Ac and Cry1C Bt resistance are not linked

(*i.e.* Cry1Ac resistant larvae cannot survive on Cry1C broccoli and vice versa)

Potential of pyramiding genes

Diamondback moth greenhouse study

Zhao et al. 2005

All cages were provided with following host combinations,

- Diamondback moth – three strains
  - 10% Cry1Ac resistant strain
  - 10% Cry1C resistant strain
  - 80% susceptible

Three types of cages used and they were provided with following plant combinations,

- Cage 1
  - 45% Cry1Ac plants
  - 45% 2-gene plants
  - 10% susceptible
- Cage 2
  - 45% Cry1C plants
  - 45% 2-gene plants
  - 10% susceptible
- Cage 3
  - 90% 2-gene plants
  - 10% susceptible

Cage 3 showed the minimum resistance development

Potential of pyramiding genes

Diamondback moth greenhouse study

Zhao et al. 2005

- **Gene pyramiding is an excellent resistance management strategy**
- **<u>However, not</u> if single gene varieties are also used**
- **Seed companies and farmers would need to agree to withdraw single gene varieties, when the pyramided gene variety was introduced**
- **But two-gene GE varieties are not always available**

Options to manage pest resistance

- **Don't forget other management practices**
  - **Crop rotation, biological control, cultural controls**
  - **Pest resistance management must happen before the problem appears**
  - **Resistance monitoring will determine the effectiveness of resistance management**

Conclusions

For managing pest resistance

- **High dose/refuge strategy may be effective but has problems**
- **Pyramiding genes appears to be a very effective way to manage resistance**
- **Additional management factors to GEvarieties may be the most effective option currently available**
- **Resistance management must be in place before a problem occurs**

Appreciation

- **The contents in this presentation are modified from the work done by Dr. E.J. Grafius, Department of Entomology, Michigan State University**
- **Special thank goes to Ms. P. Janaththani for technical assistance**