

ISSUES – FIGURE SET

What Are the Ecological Impacts of Plant Biotechnology?

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Green and red peppers, © B. W. Grant

Figure Set 3: How Engineered Genes Persist in Wild Populations

Purpose: To analyze the fitness of weed-crop hybrids. This will introduce some potential problems associated with crop biotechnology, including 'superweeds.'

Teaching Approach: citizen's argument

Cognitive Skills: (see Bloom's Taxonomy) — knowledge, comprehension, application

Student Assessment: essay

CITATION:

Zycherman, D., and J. Taylor. August 2004, posting date. What Are the Ecological Impacts of Plant Biotechnology? Teaching Issues and Experiments in Ecology, Vol. 2: Issues Figure Set #1 [online]. http://tiee.ecoed.net/vol/v2/issues/figure_sets/biotech/abstract.html

BACKGROUND

A transgene is a gene from one organism that is introduced into the genome of a different type of organism. A transgene escape is a potential problem associated with crop biotechnology. Weed-to-crop hybridization has already become a problem in that gene flow has led to the appearance of new or more difficult weeds. For example, hybridization between sea beet and sugar beet has created a weed that has severely damaged Europe's sugar production. With the introduction of genetically engineered crops, such events are expected to become more numerous because engineered genes may confer advantages to wild populations (Klinger & Ellstrand 1994).

Weed-crop hybridization can occur when pollen flows between transgenic crops and wild relatives. The resulting hybrids could establish themselves or persist for a long period and in high enough densities for the transfer of transgenes into wild populations (Linder & Schmitt 1995). If transgenic crops hybridize with nearby weedy relatives, the predicted transfer of genes will be inevitable when farmers plant these crops on a commercial scale (Marvier 2001). The movement of unwanted crop genes in the environment is possible because a single crop allele has the opportunity to multiply itself repeatedly through reproduction, making containment nearly impossible (Ellstrand 2001). Weeds resistant to herbicides are a considerable problem. Clearly, farmers do not want advantages to be transferred to weeds because their persistence could lead to lower yields due to weed damage.

One such possible advantage, of which farmers are wary, is herbicide resistance. Herbicide resistance is created in a plant by manipulating its genes to detoxify an herbicide that is sprayed on it (Simmonds and Smartt 1999). This is a beneficial trait because farmers can spray their fields with herbicides, killing weeds, while not having to worry about the effect it will have on their crops. Monsanto's herbicide, Roundup, is used by some farmers before planting because it is effective at killing almost anything green. Roundup is considered a good herbicide because its active ingredient, glyphosate, is less toxic than many other herbicides on the market. The only problem is that after crops are planted, farmers could not spray more glyphosate because, as such an effective killer, it would kill their crops in addition to weeds. Monsanto created Roundup Ready soybeans which are herbicide resistant, specifically to Roundup. The application of Roundup without killing crops can be seen as a very positive advancement in crop production for farmers.

Although herbicide resistance is a positive trait for soybeans, it can be a major problem when transferred to weeds. "Superweeds" may arise when herbicide-tolerant crops cross-pollinate with wild cousins, resulting in herbicide-resistant weeds (Orojan & Long 2000). After a certain amount of time and exposure, any species can develop a resistance to an herbicide (Marvier 2001). To prevent creation of "superweeds," some transgenic crops are made sterile which prevents transgene escape. But this means that farmers need to purchase new seeds after each season, which can be costly. Although tests of genetically engineered plants are currently being performed, the true risks may not be realized until the damage has occurred, as this is still a relatively new

technology. Therefore when the full extent of this problem becomes clear, it may be too late for us to mitigate the effects.

The figures for this Figure Set are from two *Ecological Applications* articles about fitness of weed-crop hybrids. These data will allow students to better understand how effects of escaped transgenes are measured in wild populations.

Literature cited:

Ellstrand, N. C. 2001. When transgenes wander, should we worry. *Plant Physiology* 125: 1543-1545.

Klinger, T., and N. C. Ellstrand. 1994. Engineered genes in wild populations: fitness of weed-crop hybrids of *Raphanus sativus*. *Ecological Applications* 4 (1): 117-120.

Linder, R., and J. Schmitt. 1995. Potential persistence of escaped transgenes: performance of transgenic oil-modified *Brassica* seeds and seedlings. *Ecological Applications* 5: 1056-1068.

Marvier, M. 2001. Ecology of transgenic crops. *American Scientist* Mar/Apr. 2001.

Orogan, J., and C. Long. 2000. The problem with genetic engineering. *Organic Gardening* 47.1: 42-46

Simmonds, N. W., and J. Smartt. 1999. *Principles of Crop Improvement*. Oxford: Blackwell Science.

STUDENT INSTRUCTIONS

Figures 3A & 3B

In the early 1990's, it was believed that hybridization between crops and their wild relatives occurred infrequently, even when plants grew in close proximity (Ellstrand 2001). Figure 3A is from a study in which researchers measured the spontaneous hybridization between wild radish, an important California weed, and cultivated radish (the same species), which is an important California crop. The experimenters attempted to replicate a true-life farmer scenario; they grew the crop as if multiplying commercial seed. They then surrounded the field with strands of wild radish weeds. The researchers harvested the seeds from the weeds and tested for hybrids in the progeny of the weed. In this system, the crop genes were clearly shown to enter natural populations. Then, persistence was tested by comparing the fitness (fruits and flowers) of the hybrids created in the first experiment with their non-hybrid siblings.

Figure 3B also depicts persistence of transgenes in wild populations. It looks at crop sorghum, one of the world's most important crops, which is highly compatible with and readily hybridizes with Johnsongrass, one of the world's most damaging weeds. A transgene introduced into crop sorghum could enter Johnsongrass populations because these species can spontaneously hybridize. If this transgene were herbicide resistant, Johnsongrass could become an even more problematic weed.

USDA hearing

Everyone will be assigned a group, each taking on a different role: farmers, environmentalists, or United States Department of Agriculture (USDA) employees. Within your group, study and interpret both figures.

Next, discuss with your group members the stance on crop biotechnology, with respect to weed-crop hybridization, that your role would take. Use information from both figures to support your point of view while explaining why the other side is wrong. Remember to discuss why your role has its bias (what is your motivation, etc.). You will have a maximum of 10 minutes to initially present your case.

The USDA will serve as the panel that the farmers and environmentalists are addressing. In response to each 10-minute presentation, there will be one-minute point and counter point arguments from each side. At the end of the debate, USDA will have 10 minutes to discuss the case in private and then will respond to the farmers and environmentalists' concerns and thoughts, proposing a brief course of action that should be taken.

Literature cited:

Ellstrand, N. C. 2001. When transgenes wander, should we worry. *Plant Physiology* 125: 1543-1545.

FIGURES

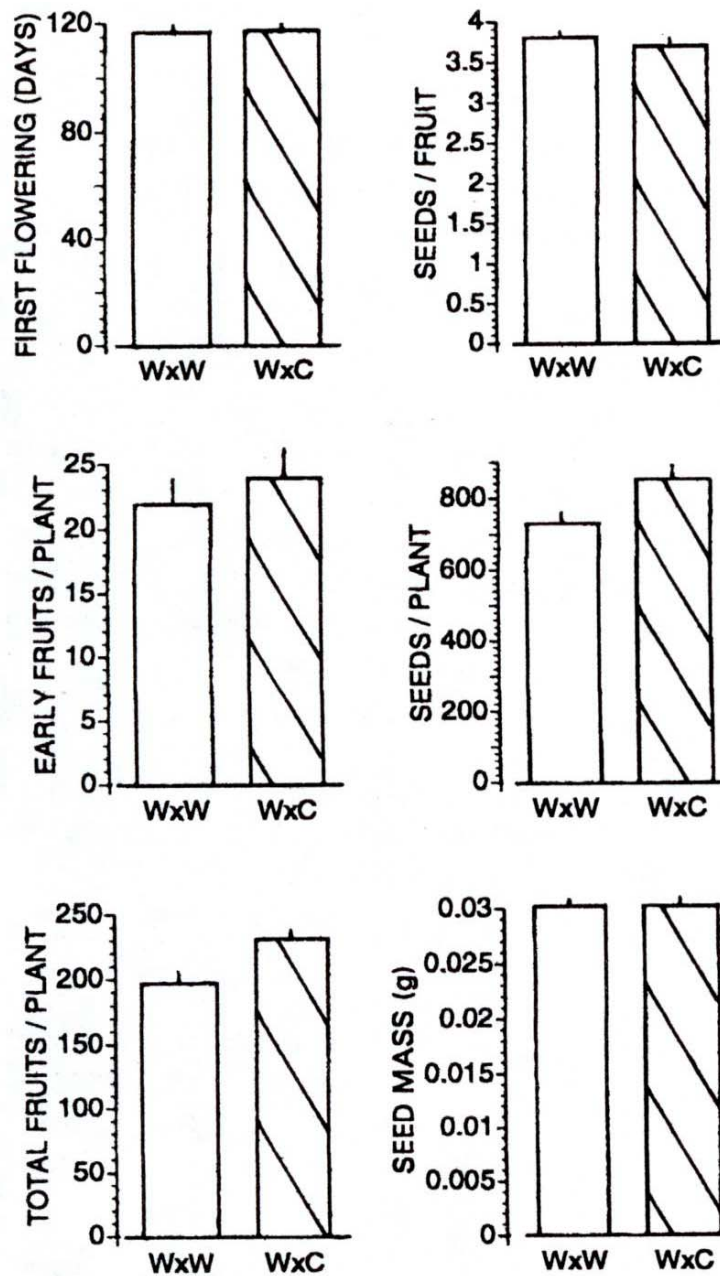


Figure 3A. Performance in wild (W x W) vs. hybrid (W x C) radish plants (from Klinger, T., and N. C. Ellstrand. 1994. Engineered genes in wild populations: fitness of weed-crop hybrids of *Raphanus sativus*. *Ecological Applications* 4: 117-120).

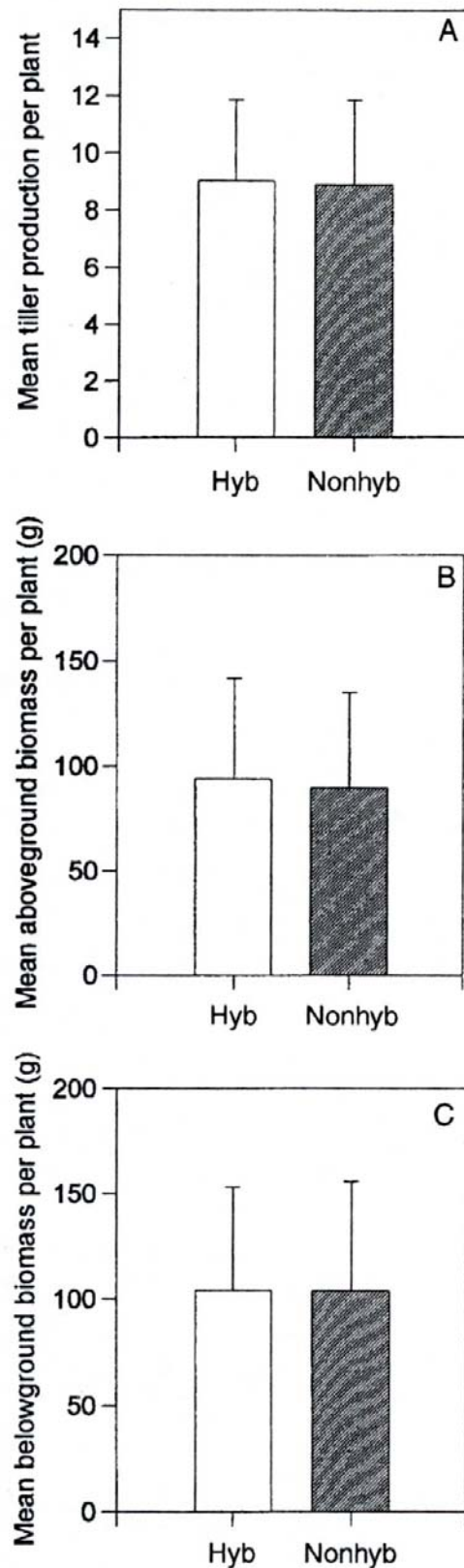


Figure 3B. Comparison of the hybrid and nonhybrid weed in terms of: (A) Mean number of tillers produced per plant; (B) Mean aboveground biomass per plant; (C) Belowground dry biomass (from Arriola, P. E., and N. C. Ellstrand. 1997. Fitness of interspecific hybrids in the genus sorghum: persistence of crop genes in wild populations. *Ecological Applications* 7: 512-518).

NOTES TO FACULTY

Figures 3A & 3B

Both experiments look at the persistence of escaped transgenes in wild populations. They measure the fitness of hybrids. Figure 3A concerns the relative fitness of weedy radishes and their weed crop hybrids. Six traits were compared to determine fitness. The two types were equal in the performance of four of the traits. However, the hybrids displayed significantly greater fruit and seed production, thus, the hybrids' fitness was greater than their wild siblings. (You will likely have to explain the term fitness in regard to the measures used here).

Figure 3B is the result of an experiment which tested for the differences in vegetative reproduction characteristics between hybrid and nonhybrid weeds. No significant differences were found between the hybrid and nonhybrid Johnsongrass plants. This lack of difference in observed fitness indicates that the hybrid weeds have an equal chance of establishing and persisting in an agricultural setting.

USDA Hearing

The Student Instructions describe a hearing in which farmers and environmentalists present a case using data from these figures plus knowledge about the topic in general. This will take a full class period and can only be done in a small class. If you do not wish to take this much time for this topic or have a large class, you can use another approach (see Table of Student-active Approaches) to stimulate a discussion.

Students will need time to prepare their 10-minute presentations and anticipate critiques from the other side. One possibility is to create the groups at the end of one class period, allowing 10 minutes or so for them to work on the figures in class. Then assign preparation for the presentations as homework, including gaining background knowledge with the some of the Resources for this issue. In the next class, give students time to polish their presentation before the start of the debate.

Make sure to allow students enough time to discuss both the scientific, social, and political aspects of this topic. After the environmentalists and farmers make their points, allow the USDA employees some extra time to make sure their position addresses the issues discussed within the debate.

Rubrics for presentations & group work assessment:

Students often have more experience writing papers than giving talks. You will need to explain what you are looking for in their presentations. An effective way to help students give more effective oral presentations is by giving them a rubric ahead of time detailing how you will judge the quality of their talks. Spend time in class discussing the rubric as well. For an explanation and an example of such a rubric see:

www.siu.edu/~deder/assess/cats/grrubi.html and
www.rickhershberger.com/bioactivesite/bio103/symposium/rubric.pdf.

It is often difficult to judge the relative input of each student when they work in groups. In an oral presentation, all students may not speak; how do you know how well each has contributed to the effort? To address this, some faculty have students assess each other. This is clearly a controversial topic for teachers. For an example of a group work assessment form see www.siue.edu/~deder/assess/cats/grp13.html. Students can fill out the form with their names or anonymously. You can choose to give the evaluations back to students or not. No matter how you choose to do group work assessment, explain the purpose of your using this type of assessment and discuss comments and ratings that are useful and ones that are not.

The intention of the Student Assessment question is for students to understand and explain the scientific evidence and information plus additional aspects (economic, political, ethical) of a point of view other than their own. As with Figure Set 1, you will probably need to explain what you are looking for here and give examples of good (and not so good) arguments. As with Figure Set 1, you are asking students to do something with which they probably have little experience: carefully consider the "other" point of view, logically support their argument with evidence, and clearly distinguish between scientific arguments and political/ethical ones. To keep the essay short, ask the students to focus on one or two aspects of their argument. Again, you may have to show by example what you mean by this.

Student Assessment:

Each student should write an essay from the perspective of one of the roles other than the one they presented in class. This essay should demonstrate their knowledge and understanding through concessions and rebuttals to the other sides. It should be approximately one page in length.

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