BEYOND THE SCIENCE

Green Genes: Sustainability Advantages of Herbicide Tolerant and Insect Resistant Crops

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A PATH FORWARD:

Focus on the use of GM crop technology, including herbicide tolerant crops, should be on ensuring wise use and best practices that provide farmers with flexibility in the field to respond to crop challenges and ensure maximum crop health. Public policy that limits farmer flexibility or crop innovations will negatively impact food production over the long-term.

- GM crop technology provides farmers with advanced integrated pest management (IPM) tools to ensure a productive and safe crop, while protecting our natural resources.
- The advent of Bt plants has dramatically decreased the use of more harmful insecticides. In some cases, the decrease has been in the range of 50 to 70 percent.
- Growers have increased their income per acre of land with the use of Bt plants and that household income also has increased.
- Weeds have always competed with crops for nutrients and sunlight.
- Management of weeds with herbicide tolerant crops ensure crop health and in the long-term have provided reduced fuel use, erosion management and improved soil conditions
- Wise management of crop tools, including selective breeding and HTC, are necessary to limit negative impacts.
- Farmers need flexibility in the field and educational support to ensure they are not over-relying on a single approach.

DEFINING SUSTAINABILITY

Sustainability has become a buzzword to the general public, but one that has particular relevance to agriculture. But what is it, really?

The National Academies of Sciences (NAS) which is charged with providing independent, objective advice to the nation on matters related to science and technology, began a forum in 2002 for sharing views, information and analyses related to harnessing science and technology for sustainability. In 2011, a branch of NAS presented a framework for incorporating sustainability into the Environmental Protection Agency's (EPA) principles and decision-making.

The committee that developed the framework used the definition of sustainability based on a declaration of federal policy in the 1969 National Environmental Policy Act and included in a 2009 Executive Order:

"Sustainability is based on a simple principle: Everything that we need for our survival and well-being depends, either directly or indirectly, on our natural environment. Sustainability creates and maintains the conditions under which humans and nature can exist in productive harmony, that permit fulfilling the social, economic, and other requirements of present and future generations. Sustainability is important to making sure that we have and will continue to have the water, materials, and resources to protect human health and our environment."

The 2011 report recommends that the EPA formally adopt as its sustainability paradigm the widely used "three pillars" approach, which means considering the 1) environmental; 2) social; and 3) economic impacts of an action or decision. The report said that health should be expressly included in the "social" pillar and that EPA should also articulate its vision for sustainability, and develop a set of sustainability principles that would underlie all agency policies and programs.

So much for the policy definitions, but what does sustainability really mean in agriculture?

FIRST, DO NO HARM

"Sustainable agriculture" contains many ideas, but the core is that agriculture should have the capacity to endure long-term. This also means that large fluctuations in one of its three pillars (environmental, social, economic) are moderated and not subject to great disturbances.

Sustainable agriculture should embrace these principles to ensure the production of food and fiber crops that are safe for the consuming public, do as little damage to the environment as possible, and are profitable for growers.

Agriculture does not occur in "natural systems" as many might think. Food and fiber are produced in "managed systems" so the challenge is to do so in a sustainable manner. New technologies such as genetic engineering are needed to meet the mandate of sustainability in agriculture.

Rachel Carson's seminal book, *Silent Spring*, was published in 1962 and is widely credited with helping launch the modern environmental movement in America. The book alerted society to the dangers of overuse of broad-spectrum pesticides. Carson recognized the need to protect crops and to avoid the harm of diseases like malaria, which are transmitted by insects. But she also saw the environmental harm that could come from overusing pesticides.

Carson wasn't the first one to recognize this, but she caught the world's attention. Three years earlier, a group of entomologists published a ground breaking concept called integrated pest management (IPM) in which strategies to avoid the pest populations were used first, and pesticides were used only when needed. A key concept in IPM is to utilize plants that are resistant to key insect pests and reduce the use of broad-spectrum insecticides so that natural enemies would be conserved and thereby help reduce the occurrence of pest insects.

In her book, Carson details the long and safe use of the soil bacterium, Bacillus thuringiensis (Bt) which, when sprayed on plants and ingested by insects, causes their death. Bt contains a protein that, when ingested by certain species of pest insects, binds to cells in their gut and makes them stop feeding and die.

Sprays of Bt have been used for decades by farmers, especially organic farmers, who are restricted from using most synthetic pesticides. However, when Bt is sprayed on plants it only lasts for a couple of days and every part of the leaf and stalk of the plant must have sufficient coverage for it to be effective. These factors have greatly limited its effectiveness and therefore it only accounts for a very small (about 1 percent) of the global insecticide market. Bt certainly had (and continues to have) supporters, but on a national and international scale its market is very limited.

Fast-forward to 1997 when the first genetically engineered plants were commercialized. These plants expressed the same protein from Bt that Carson had advocated and that some farmers used in Bt sprays. But now that the protein was expressed *in* the plant, as opposed to being sprayed *on* the plant, it provided effective coverage and did not have to be sprayed every few days. It is essentially the same protein as the spray, but produced by the plant.

GENETICALLY MODIFIED CROPS CAN FOSTER MORE SUSTAINABLE PRODUCTION SYSTEMS

Besides meeting the goal of having a positive impact on the environment and the economic well-being of farmers and consumers, Bt plants meet the social equity demands of sustainability because they can be grown by small, resource-poor farmers as well as by those who are less resource constrained. In fact, on a global scale, more farmers in developing countries grow Bt plants than in developed countries.

SIX FACTORS ACCOUNT FOR WHY BT PLANTS ARE SUSTAINABLE:

1. **The plant is manufacturing its own defense against an insect that is trying to colonize it so growers do not need to drive through the fields to reapply an insecticide and thereby use fuel and compact the soil.**
2. **Studies show that Bt does not harm natural enemies (predators and parasites) that help suppress populations of pest insects.**
3. **Studies show that insects will develop resistance to the Bt protein when it is sprayed on plants much faster than to the same proteins when it is expressed <u>in</u> the plant. Although there are a few isolated cases of insects having evolved resistance to Bt plants, there are far more cases of resistance to other insecticides.**
4. **The advent of Bt plants has dramatically decreased the use of more harmful insecticides. In some cases, the decrease has been in the range of 50 to 70 percent.**
5. **Studies document that growers have increased their income per acre of land with the use of Bt plants and that household income also has increased.**
6. **The environmental impact of Bt plants is much lower than when non-Bt plants are used.**

Bt plants are not a panacea and must be managed properly, like any technology, to ensure their long-term durability. They will not, by themselves, eliminate global malnutrition. No crop technology will do that. But Bt plants that reduce or eliminate the need for insecticides can be an important part of the global food and fiber system and help move us to more sustainable agricultural production systems. They should be part of integrated pest management.

Shelton, co-author of this paper, is an entomologist who came into agriculture because of the influence of Rachel Carson. "Once a year I go back and scan the last chapter of *Silent Spring*, in which Carson challenges us to find alternative methods of managing insect pests. She asks why we don't use microbial insecticides that are specific to insects and don't harm humans. I think that Rachel Carson would applaud their use since she strongly promoted Bt as an alternative to the harsher insecticides used in her day," said Shelton. "I think she would simply say, '… same protein, better delivery system.'"

BENEFITS OF HERBICIDE-TOLERANT CROPS

What about herbicide tolerant crops? Weeds force crops like corn and soybeans to compete for sunlight and nutrients. Herbicide-Tolerant crops (HTCs) contain genes that enable them to degrade the active ingredient in herbicides, rendering them harmless. Farmers can thereby easily control weeds during the growing season and have more flexibility in choosing times for spraying.

HTCs were developed through decades of research in biotechnology and genetic engineering. These technologies enable us to identify useful genetic traits in plants or microorganisms and transfer the DNA that encodes that trait into a plant that can use that trait effectively. In the case of HTCs, microorganisms had the ability to metabolize the herbicide rapidly, which, when transferred to a crop plant, enabled it to tolerate the herbicide when it could not before the transfer of that DNA.

Since the first HTC was developed, we've developed a number of additional herbicide-tolerant traits that can also create either a target site enzyme that is not sensitive to the herbicide, or produce products that overcome the herbicides mechanism of action.

These crops allow farmers to more effectively control weeds, thus improving yield and quality. Weed control is usually the most expensive area of a farming operation, so crops that can survive being sprayed with an herbicide help keep farms economically viable. The effectiveness of weed control with HTCs has also allowed farmers to adopt conservation tillage. Instead of plowing fields every year, farmers are able to leave the previous year's corn stalks or soybean stubble before and after planting to reduce soil erosion and improve soil quality. This has led to reductions in surface water contamination from sediment and nutrients.

HTCs also have allowed producers to become more efficient, since they are able to spend more time on other aspects of their farm instead of fighting weeds. We are now able to produce more crops with higher yields and better quality, which is critical if we are to feed a world population of over 7 billion today and expected to top 9 billion by the year 2050. We are also using HTCs in ways that protect our environment and create more sustainable cropping systems, since we can significantly reduce tillage. Tillage has always primarily been focused on weed control, so providing tools that can enhance or replace tillage have many positive environmental benefits – such as reduced fuel use and improved soil conditions.

HOW BIG A PROBLEM ARE HERBICIDE RESISTANT WEEDS — SO-CALLED ‘SUPERWEEDS’?

This is one of the most pressing issues facing agriculture today. Herbicide resistance has been an issue since shortly after selective herbicides (those that kill undesirable plants while leaving desirable plants unharmed) were first developed in the 1950s. With the majority of soybean, corn, cotton, and canola acreage now planted with glyphosate-resistance traits (glyphosate was marketed in the 1970s under the trade name Roundup), we are faced with losing the effectiveness of the most significant herbicide globally.

As has occurred in the past, when growers repeatedly use the same mechanism over and over, selection pressure for the evolution of resistance builds. Much of the discussion has focused on glyphosate resistance, because millions of acres of soybeans, corn, cotton, and canola have relied exclusively on glyphosate for weed control for a number of years. With that kind of intense selection pressure, development of widespread resistance to glyphosate was inevitable.

Because of the positive impact of glyphosate for effective weed management around the world, many have called for regulation of herbicide resistance to preserve this vital technology. However, it is difficult to envision how regulation could be an effective tool. Each grower’s situation in each field, or even portion of a field, changes in terms of weed population, cropping system and rotation, environmental conditions, government compliance issues, etc. Prescriptive regulation would by necessity have to be so generic that it would be of questionable value.

IF NOT THROUGH REGULATION, HOW CAN THE ISSUE BE ADDRESSED?

One option would be for the stipulation of herbicide resistance management strategies on the herbicide label itself for the product to be used. This idea has real merit because it would be an official document calling attention to the need for a strategy. The challenges with this approach are in monitoring compliance, and in determining who is qualified to develop herbicide resistance management plans, and in how compliance monitoring and plan development would be funded.

Various incentive programs, public and private, are being explored, and have tremendous potential to help overcome the initial hesitance to adopt sound resistance management program development. Community-based approaches to herbicide resistance management are also being explored, and in some cases have proven successful.

By far the most effective means is through education and training for prevention and mitigation. If growers and decision-makers are given the appropriate training and information on the impact of resistance development, they can be equipped to develop effective herbicide resistance management strategies. But the education must be more than simply providing scientific information. We must also provide a complete understanding of the suite of best management practices, a complete understanding of the economics of resistance management, and an understanding of the decision-making process so that growers are given information that fits their specific situation. We can’t look at development of herbicide resistance merely as a technological problem, but rather, as a human-induced issue. Viewed through that lens, education programs must be developed to change the way decisions about weed management are changed, both short- and long-term.

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