BACKGROUND INFORMATION

PART 1

Growing Food Challenge

Plants growing in a natural environment face several challenges that affect which plants will survive and grow, produce seed, and complete their life cycle. Various pests such as weeds, herbivores, and pathogens can threaten plant production of grain, fruit, or flowers. Cultivated plants can have other stressors such as dry weather or a lack of soil nutrients. As a result, growers often manage their fields to reduce stress through methods such as irrigation, fertilization, and pest control to increase crop production.

Crops and their environment have an impact on each other. In agriculture, various approaches impact water use, pesticide use, and CO_2 release (**carbon footprint**). Tillage practices, fertilizer use, conventional pesticides, biopesticides, etc., are all factors that impact a crop's environmental footprint. **Environmental footprint** is the effect that a person, company, activity, etc., has on the environment, e.g., the amount of natural resources that a crop uses and the amount of harmful gases it produces.

Official Definition of Pest – An organism is declared to be a pest under circumstances that make it deleterious to man or the environment, if it is: (a) Any vertebrate animal other than man; (b) Any invertebrate animal, including but not limited to, any insect, other arthropod, nematode, or mollusk such as a slug and snail, but excluding any internal parasite of living man or other living animals; (c) Any plant growing where not wanted, including any moss, alga, liverwort, or other plant of any higher order, and any plant part such as a root; or (d) Any fungus, bacterium, virus, prion, or other microorganism, except for those on or in living man or other living animals and those on or in processed food or processed animal feed, beverages, drugs, and cosmetics. (U.S. Code of Federal Regulations)

Approaches to pest control include mechanical, biological, chemical, or cultural techniques. Some growers also use **Integrated pest management (IPM)**, a decision-making framework that helps growers decide when to apply pest control and which control techniques to use. IPM focuses on long-term pest control and aims to minimize pest impact on crop quality.

Methods of Pest Control in Crops

Method	Examples
Mechanical	Tilling, Mulching
Biological	Biological pesticide, Beneficial insects, Disease-resistant plant varieties developed through conventional breeding or GE methods
Chemical	Pesticides, Insecticides, Herbicides, Fungicides, Nematacides, Rodenticides, Bactericides
Cultural	Irrigation, Crop rotation, Mixed cropping, Cover cropping, Row covers, Sanitation

MECHANICAL PEST CONTROL

Plant pests can be controlled in many ways. Simply pulling weeds from a garden or flower bed reduces the competition for moisture and plant nutrients and helps avoid the insects those weeds might attract and harbor. This is known as a physical or mechanical control method of plant protection. Plant pest control often starts with preparing a site to make it harder for pests to survive. For example, a grower might **till** (turn over) the soil or put down mulch cloth to reduce weeds. Reduced tillage systems are also common and have certain benefits, such as reduced soil erosion.

Farmers can use different tilling methods to prepare soil before planting. **Reduced tillage** includes different approaches that conserve soil by leaving more plant residue on the soil surface and uses less energy. **No-till** is a method that leaves the soil undisturbed through use of a coulter (a vertical blade) that slices the soil, and another tool that places the seed at a proper depth. However, even in no-till systems, farmers may need to till every few years to reduce crop debris that could harbor crop pests such as insects and pathogens. **Conventional tillage** normally involves three or more steps using tractor-pulled tools. The environmental footprint varies with different tillage methods of pre-planting soil preparation.

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BIOLOGICAL CONTROLS

Biological controls are more complex than simply plowing a field. They use a biological organism or process to protect plants from damage caused by other organisms. Several types of natural or biological plant protection innovations have been developed throughout farming history. The most commonly used are:

1. Selective breeding to cultivate damage-resistant plants
2. Use of beneficial organisms to control weeds or insect populations
3. Biopesticides produced from microbial cultures, plants, or other organisms
4. GE plants designed to resist pests

Biological Control Using Predators

Biological control with predators uses an organism (such as an herbivore, predator, pathogen, or parasitoid) that consumes the pest to reduce pest populations. For example, predator insects such as lady beetles and lacewings eat other insects. Parasitoid insects such as wasps lay their eggs on or in some life stage of the target insect. After an egg hatches, the developing immature stage of the parasitoid insect kills the targeted host by consuming the host tissues. Biological control might also involve releasing beneficial organisms to the environment or changing the landscape to increase populations of beneficial organisms.

Limitations of Biological Control Using Predators

There are limits to the safety and effectiveness of biological insect control. For example, it may be necessary to eliminate or reduce the use of broad-spectrum pesticides, since both beneficial and target insects could be killed. Fungicides used against plant pathogenic fungi can also impact desired fungi when applied to reduce insect pests. In addition, strict regulations must be used to ensure that today's insect predator will not become tomorrow's pests.

Managing an insect attack can be complicated, because the attacking predatory or parasitoid insects cannot thrive until there are sufficient numbers of target insects to serve as prey or hosts. Some biocontrol insects may also destroy a broad range of insects – both beneficial and harmful. Sometimes beneficial insects can be considered pests when they become too numerous or are in the wrong place. Invasive lady beetles from Asia have displaced some native species in the United States. They can also become minor pests in the home when they invade in large numbers when weather starts to turn cool.

CHEMICAL CONTROLS

Pesticide use is one of many management practices in agriculture. Continuous pressure to feed increasing populations has influenced agriculture to progress through many stages from domestication and improvement of crop plants, to mechanization, fertilization, and pesticide use. Pesticides are applied to crops, gardens, animals, lawns, recreational areas, and around homes and other buildings. They help provide abundant, disease-free, pest-free foods, improve crop yield, and reduce disease vectors for humans, animals, and plants.

Pesticides were considered necessary in crop production in the mid-twentieth century and were often applied in multiple passes across the field. Pesticides still are considered necessary in crop production, but improved technology provides pesticide options that are more compatible with other control methods and reduce environmental consequences. In addition, more judicious pesticide application has evolved over time, with application following field scouting to ensure that pesticides are only applied when there is a danger that pests may reach levels that significantly impact a crop's sale value.

DID YOU KNOW?

Many plants have evolved to produce natural compounds to defend themselves from pests. Some of these substances are potentially harmful to animals (including humans) that eat the plants. How harmful a consumed substance is for humans or animals varies depending on exactly what the substance is and how much is consumed (the dose).

There are different types of pesticides such as herbicides, fungicides, insecticides, rodenticides, etc. Different herbicides are designed to be most effective at different timings: Some are only applied before planting to control germinating weed seeds, and others are applied after the crop plants emerge.

Pesticides are often used to solve plant pest problems, but if they are used incorrectly, some of them might not provide the desired results or can harm crop plants or the environment (including groundwater, lakes, or rivers). Pesticides are evaluated for their impact on the environment and for how they may affect the health of people who may be exposed to the pesticides. The Environmental Protection Agency (EPA) works with the U.S. Department of Agriculture (USDA) and the Food and Drug Administration (FDA) to monitor use of chemicals in food production and determine levels of safe use.

Pesticide Impact on Humans

Pesticides may contain chemicals with possible health risks to humans. The risk is determined by the hazard and exposure, i.e., how someone comes into contact with the pesticide (ingested, inhaled, or through skin contact).

The EPA classifies pesticides based on their chemical toxicity and separates them into four categories – Category I, II, III, or IV, with Category I chemicals being the most toxic. Using these categories, EPA restricts where the pesticide can be applied, how much can be applied, and also anticipates its possible exposure level to humans.

Pesticide Impact on the Environment

Some pesticides can contaminate soil, water, turf, and other vegetation. In addition to killing insects or weeds, pesticides can be toxic to other organisms including birds, fish, beneficial insects, and non-target plants.

For the last 30 to 40 years, researchers have been developing pesticides that are more specific to their target pests and that have a reduced impact on the environment. Different pesticides also break down at different rates, which are further influenced by conditions such as moisture and temperature.

A **Risk Quotient (RQ)** is used to quantify the environmental impact of most commonly used pesticides (insecticides, fungicides, and herbicides) in agriculture and horticulture. The RQ value is calculated using key factors such as a pesticide's active ingredient(s), toxicity, amount applied, and how long it persists in the environment. RQ values allow pesticide options to be compared.

Biological Pesticides (Biopesticides)

The most widely applied bacterial species used as a biological pesticide is *Bacillus thuringiensis* (*Bt*), a bacterium found in soil. *Bt* produces a natural crystal protein that is toxic to some other organisms like insects and nematodes. Some strains of the *Bt* bacterium produce toxins that are naturally highly specific to certain pest insects, but harmless to most other organisms. When *Bt* produces spores, a toxic crystal protein is formed inside the spore. The spores are suspended in a liquid and sprayed on the plants. When a targeted pest eats the spores, the crystal toxin is released, and the pest will die. *Bt* spores are regarded as safe to humans and the environment because they are so specific to a few types of insects.

There are many other natural organisms that can be used to produce a biological pesticide. Researchers in Florida are growing a naturally occurring fungus, *Hirsutella citriformis,* to fight the Asian citrus psyllid (jumping plant lice). Asian citrus psyllids are small insects that feed on citrus plants. They can transmit the bacteria that causes citrus greening disease to their host plants.

Citrus greening is one of the most serious citrus plant diseases in the world and affects many citrus trees in Florida and the South. It is also known as Huanglongbing (HLB) or yellow dragon disease. An infectious virus of citrus known as Citrus tristeza virus (CTV) is being evaluated as a vector of biologically active peptides targeting the HLB bacterium into the cells of the citrus trees. While CTV is a pathogen of citrus, it can be used as a biological control of HLB in this case, because it uses CTV strains that have been selected to cause only a few mild symptoms when trees are infected.

Tillage methods influence pest control. In conventional tillage, few selective herbicides may be needed because the tillage helps to control weeds. Reduced tillage and no-till systems may require broad-spectrum (less selective) herbicides because there is less tillage. However, reduced tillage and no-till systems may have benefits such as enhanced nutrient cycling and water retention. Conventional tillage releases the most greenhouse gas when stored carbon in the soil is released into the atmosphere and more fuel is used for power tilling equipment.

DID YOU KNOW?

Some people think all food that is labeled "organic" was grown without pesticides. However, there are many "organic" pesticides approved for use in growing food crops that can be labeled "organic." *Bt is* an organic pesticide. For a complete list of allowed and prohibited substances, see USDA's National Organic Program list: **www.ams.usda.gov/about-ams/programs-offices/national-organic-program**

FOCUS ON GE PLANTS

GE Plants with Enhanced Traits (Biotechnology)

Several GE crops have been developed specifically to be **insect resistant (IR)** or **herbicide tolerant (HT)**. IR *Bt* GE crops have been designed to produce a protein that kills specific target insects, such as the European Corn Borer, when they attack the plant. These proteins only affect specific receptors in the gut of certain target pests and are harmless to humans, mammals, and most non-target insects.

One unanticipated consequence of this pesticide specificity is the resurgence of some secondary pests (e.g., cutworms, wireworms) that are not targeted by the *Bt* endotoxin and can become primary pests in some years, in some locales. HT crops are designed to tolerate specific broad spectrum (non-selective) herbicides, which kill surrounding weeds but leave the cultivated crop intact. Glyphosate-tolerant crops are the most prevalent, although many new combinations of HT mechanisms are also used with older herbicides, such as dicamba, that are used commercially. In addition, HT traits are not required for reduced tillage or no-till practices, but they can make it easier for farmers to use these practices.

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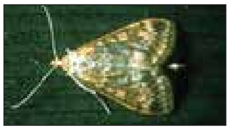
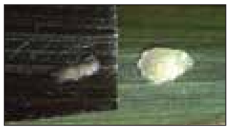
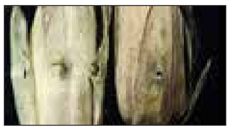
European Corn Borer


adult female


eggs


pupa


larva


husk injury


stalk damage

Photo credit: Pennsylvania State University Entomology Department

Biotechnology Approaches to Combat Plant Diseases

According to CropLife International (an association that promotes agricultural technologies such as pesticides and plant technology), more than a third of the world's potential crop production is lost each year to pests and plant diseases. Most crops can be damaged by diseases caused by soil-borne plant pathogens and insect-vectored viruses. The three predominant types of plant disease agents are viruses, bacteria, and fungi.

- Combating viral diseases: Scientists have transferred virus genes, such as those that produce a virus coat protein, into plants. This acts like a vaccine that makes the plant resistant to that specific virus. Another way to increase plant resistance to viral infections is to inhibit the vectors, such as insects and nematodes, that carry the virus.
- Combating bacterial diseases: All crop plants are susceptible to bacterial infections. Bactericides, including antibiotics, are not a complete solution, because bacteria quickly evolve resistance to them, and this could have implications for treatment of infections in man and animals.

  Fire blight is an example of a harmful bacterial disease that destroys pears, apples, quince, and some ornamental plants. One remedy is to spray trees with large quantities of antibiotics. Scientists have identified DNA markers for fire blight resistance and are working to develop resistant varieties.
- Combating fungal diseases: Fungi cause billions of dollars in crop losses each year. They attack nearly all fruit, vegetable, and grain varieties. Some plants are more susceptible to fungal diseases than others, simply because they are too slow to start fighting back after they are attacked, or they lack the resistance gene for that particular fungus. Some techniques can trigger these plants to respond sooner by treating them with fungal pathogens that have been disarmed, or by using resistance inducers like salicylic acid, a naturally occurring plant biochemical, making the fungus harmless to the plant.

DID YOU KNOW?

Viroids, algae, and parasitic plants can also be disease agents or pests of crops. Viroids are similar to viruses but without the coat protein and with their own unique properties; they are folded RNA molecules with secondary structure and can cause significant diseases, e.g., potato scab.

Environmental Impact of Growing GE Plants

GE crop technology has been used widely since the mid-1990s in several countries and has mainly been used in four main crops: canola, maize, cotton and soybean. The adoption of GE IR and HT technology has significantly reduced certain insecticide and herbicide use. Source: **www.ncbi.nlm.nih.gov/pmc/articles/PMC6277064/**

Generally, less fuel is consumed in the production of major GE crops because the HT traits make no-till practices easier to use, which results in lower carbon dioxide emissions. Specifically, HT GE crops require less tilling. The no-till process requires effective herbicide control of weeds in lieu of mechanical tillage and is facilitated by the adoption of HT crops. Farmers use less fuel because fewer passes are made through the field to till and to spray herbicides on GE crops.

The no-till method also reduces erosion on susceptible land in steep terrain or fragile landforms and reduces chemical use. The use of plants modified to resist corn borer and rootworm has also decreased insecticide use. These production practices allow GE crops to have increased yield, which also makes food cheaper to produce on less land.

GE crops are sometimes blamed for lowering genetic diversity of crops and speeding the development of herbicide resistance in weeds. However, when farmers use seeds from fewer family lines, diversity decreases regardless of whether GE or non-GE seeds are used. In addition, herbicide use can result in the selection of weeds resistant to the herbicide in GE or non-GE crops. Herbicide-resistant weeds have long been a concern for farmers. The availability of HT GE crops has arguably resulted in faster selection of weeds resistant to the herbicide, but GE crops with multiple HT features could also help slow the selection of herbicide-resistant weeds.

How serious is weed resistance to pesticides?

In the United States, there are currently 14 weeds associated with common crop production that are resistant to the most popular non-selective, post-emergent herbicide. From the International Survey of Weed Resistance: **www.weedscience.org**