Mining for Phytochemicals: A Multifaceted Effort

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Unlike in animals, the “fight or flight” response isn’t an option for imperiled plants—including those grown as crops for our food, fuel, and fiber needs. A plant, for example, cannot simply uproot itself and sprint to safety from an approaching caterpillar.

But plants can defend themselves, and they’ve done so for millennia, by using an abundance of potent secondary compounds broadly referred to as “phytochemicals.” Some, like glyceollins in soybeans, are produced only in response to a specific threat—similar to the adrenaline surge a person experiences from a life-threatening event. For plants, this threat can be from a grazing animal, the first few chomps of a hungry insect, or the germination of a fungal spore. Other phytochemicals are “constitutive,” meaning they occur continuously to protect vital plant parts. An example is capsaicin, which occurs in chili pepper seeds and gives the fruit its tongue-torching “heat.”

Both phytochemical types have been the focus of scientific attention and formal study for well over 100 years. Agricultural Research Service scientists have been on the forefront of such studies and today conduct projects investigating the defensive responses of plants at laboratories in Peoria, Illinois; Gainesville, Florida; Oxford, Mississippi; Prosser, Washington; and other locations. All of these projects ask the question, “If plants can make their own natural chemical defenses, why the need for synthetic pesticides?”

In part, the answer has to do with the thousands of years of agriculture that preceded our modern-day understanding of plant genetics and advanced breeding technologies. The result of this nascent period was the loss of many plant-beneficial traits in favor of a few desirable ones singled out by humans. In some cases, where phytochemicals imparted a bitter or undesirable taste (such as alkaloids, a group of compounds believed to function mostly as plant protectants), selecting for plants with lower levels of those phytochemicals may have been deliberate. In either case, the result was a greater need for human intervention in protecting the plants from pests that they once may have been able to defend against on their own.

Here’s another consideration: Even if a crop retained its natural protectants through these early breeding practices, cultivating plants with a limited genetic diversity under unnaturally high densities would have likely resulted in pest pressures reaching levels requiring human intervention.

Additionally, insects and pathogens are notoriously adaptable and can evolve biotypes possessing resistance to the pesticides used against them. The emergence of resistant biotypes can also imperil plants, such that a particular natural defense becomes ineffective. This, in turn, necessitates the development of new strategies, including new pesticides with novel modes of action and the selection for plant traits that defeat or minimize the impact of the pest.

Another approach is to study the genes, biosynthetic pathways, structure, and function of phytochemicals for new clues to shoring up the defenses of today’s crops. This may involve activating long-dormant genes or getting them to activate more quickly and to a greater degree. Engineering new biosynthesis pathways may help plants express phytochemical defenses where and when they’re needed most—and not just against insects or pathogens, but also weeds. For example, ARS researchers in Gainesville have identified 10 compounds in corn that help the plant fend off fungal infection and insect feeding. (Story begins on page 4.)

In addition to the potential environmental benefits of using what plants already have to offer, there are nutraceutical and pharmaceutical gains to be realized: Some of the same phytochemicals that plants use to protect themselves or cope with stress can also benefit humans and livestock animals when consumed. ARS researchers in Peoria, Illinois, for instance, are investigating saponins from soybeans that not only deterred caterpillar feeding in trials, but also diminished growth of cancerous human colon cells in test-tube experiments. Resveratrol, an antifungal agent in grapes, blueberries, cranberries, and other plants, is another subject of biomedical interest, and the field of ethnobotany examines the medicinal, religious, cultural, and other uses of plants by people.

Whether it be for human health benefits or crop protection, we still need to learn more about the regulation and interaction of genes involved in the production of phytochemicals—and what the cost is to the plant if they’re manipulated for elevated expression levels.

More than 100 years of scientific study may have passed, but much has yet to be learned about the fascinating phytochemical story of plants. Then, as now, ARS researchers will continue to “read between the lines,” ferreting out the meaning and practical implications for improved crop productivity, as well as human and environmental health.

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