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Shining Some Light on the Sunflower

by Randolph Fillmore

By identifying the genes that distinguish the domestic varieties of this commercially important plant from its wild cousins, a UGA researcher strives to improve its agricultural traits.

The domesticated sunflower Helianthus annuus, with its golden face and stately height, is the passion of UGA plant biologist John M. Burke, who is seeking clues about the evolution of wild and domesticated varieties. In particular, he and his colleagues aim to discover which genes were influenced by ancient Native American "genetic engineers" in their efforts to make the plants more productive and easier to work with.

Domesticating the wild varieties of corn, beans and rice involved a relatively small number of genes, Burke said, perhaps as few as five in the case of corn. But wild and domesticated sunflowers differ from each other by a much larger number of genes, each with a more subtle effect.

Thus "although the sunflower is one of the world's most important oilseed crops, we don't have a full understanding of the genetic basis of its domestication," said Burke. "As we identify the molecular markers associated with desirable traits in the sunflower, and ultimately the underlying genes, our research will have a positive impact on its continued improvement as a crop plant" in terms of properties such as seed dispersal, flowering time, plant yield and nutritional value. His work is being funded by the National Science Foundation and the U.S. Department of Agriculture.

A Widely Popular Crop

Native Americans first domesticated sunflowers from wild plants some 4,300 years ago in what is now the central United States. Eventually, they planted sunflowers across North America, combining the seeds with other vegetables, crushing the seeds into flour for baking, or eating them alone as a snack. The sunflower's oil also served many purposes, from a snakebite medicine to hair and skin beauty aids.

Intrigued by this plant, 16th century Spanish explorers of the New World took sunflower seeds to Europe. Peter the Great later brought

them to Russia, and his compatriots eventually began commercializing sunflower-seed oil in the early 19th century. In the south of France in the late 1880s, Vincent van Gogh fell in love with sunflowers and painted them often.

Sunflowers finally came back home to North America in the 20th century, where they are now abundant in the wild and are also widely planted as a commercial crop, mostly in the Plains states. Millions of gardeners nationwide also grow them for their happy, graceful but short-lived beauty.

Escaping to the Wild

As agriculturally produced crops are genetically improved, an important issue is how to keep domesticated plants from cross-pollinating with wild strains via gene flow, the process by which biological populations naturally mix their traits. Not surprisingly, Burke and his colleagues are particularly interested in how cultivated sunflowers may affect wild populations.

“The transfer of genes from crop plants to their wild relatives via hybridization is one of the risks associated with commercializing genetically engineered crops,” said Burke. “And there is great potential for reproductive contact between cultivated and wild sunflowers because the vast majority of all cultivated sunflower fields in the United States occur in close proximity to wild sunflower populations.”

According to a study that Burke and colleagues published in the September 2002 issue of the American Journal of Botany, there was evidence of crop-wild hybridization in 10 to 33 percent of the sunflower populations they surveyed. This fact raises the broader agricultural issue of any engineered crop’s genes, or “transgenes,” escaping to wild relatives. The problem of genetically modified corn genes, for example, establishing themselves in non-modified fields has already become an agricultural, legal and ethical issue.

Close proximity should not be a problem if crop plants and their wild relatives flower at different times, but that’s not the case with sunflowers. If an engineered gene provided an advantage such as herbicide- or disease-resistance, hardier and more invasive weeds could result, said Burke.

Potential Fixes

Still, Burke pointed out that “there are numerous suggestions as to how to minimize the risk of transgene escape.” In one such strategy, many plant biologists are developing ways to keep genetically modified crops from sowing their seeds where some farmers don’t want them. But gene-containment strategies have drawbacks because all such methods currently tend to be “leaky,” according to Burke.

An alternative approach would be to offset the advantage provided by an engineered gene by inserting it into the plant's DNA in close proximity to a crop gene that is potentially harmful under natural conditions. "Rather than attempting to stop the initial escape of an engineered gene, one might neutralize their effects by linking them to genes that are good for crops but bad for wild plants," said Mark Chapman, a postdoctoral researcher in Burke's lab.

For example, a programmed genetic tendency not to disperse seeds is advantageous in a crop field where plants need to hold their seeds until harvest. But this same trait is clearly a disadvantage in the wild, where the ability to spread seeds without difficulty is important to the species' spread. By handicapping that genetic trait, it could safely be applied to domesticated crops.

Fruits of Further Study

While studying sunflower genetics, Burke and colleagues have also found a clue to the history of sunflower domestication that may help answer the question of whether van Gogh's favorite flower was domesticated on more than one occasion. Some researchers had suggested, for instance, that southern Mexico was the site of an independent domestication event.

In their search for evidence of the hypothesized Mexican origin, Burke and colleagues investigated patterns of gene-sequence variation in the chloroplasts (plant cells responsible for photosynthesis) of wild and cultivated sunflowers. Because the DNA of this specialized subcellular structure is handed down from a maternal plant to its seed, its examination is useful for determining lineage. Burke's team found that all of the cultivars they surveyed harbored a single chloroplast type, even when there were many different forms present across the geographic range of wild sunflowers.

"Our results suggest a single North American origin of extant domesticated sunflowers," said David Wills, a graduate student in Burke's lab. "Of course, we can't rule out the possibility of a Mexican domestication event, the descendant of which ultimately went extinct."

While sunflowers both wild and domesticated will continue to show their shining faces and perhaps inspire other painters, regardless of the plants' ancestry, they will certainly inspire scientists. Burke is confident that his lab's research will make contributions both to the basic and applied sides of plant biology.

"Our work is resulting in the development of permanent genetic resources," he said, "both for evolutionary biologists and crop scientists."