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Morning glories creeping their way around popular herbicide, new UGA research reports

Morning glories are beloved mailbox flowers all over rural America, but to farmers, they are something else: a noxious weed that can lower yields and choke harvesting combines. For some 30 years, however, the herbicide glyphosate has kept morning glories quite effectively out of farm fields.

Now, for the first time, however, researchers at the University of Georgia have identified morning glory families that are tolerant to glyphosate – noxious vines that could cause problems for the country's farmers.

"Our study suggests that serious and immediate consideration should be given to developing regional strategies for managing the evolution of tolerance in morning glories," said Regina Baucom, a doctoral student at UGA who directed the research.

Baucom and UGA assistant professor of genetics Rodney Mauricio co-authored the study, which is being published this week in the Proceedings of the National Academy of Sciences. The research was funded by the National Science Foundation and a research grant from Sigma Xi.

The tolerance of some morning glories to glyphosate is a naturally occurring trait, not something caused by the application of RoundUp®, and other herbicides that contain the chemical, which is used on millions of home lawns and gardens as well as farm crops. The problem is that the chemical does kill most morning glories quite effectively so that the tolerant ones could be the "last weed standing" and leave farmers without an effective means of control.

The current study does not address the practical concerns of agriculture however. Rather, it examines genetically how morning glories – both those that are not killed by glyphosate and those that are – lose or maintain the ability to produce offspring for future generations.

The issues are complex. The use of herbicides and pesticides has allowed dramatic increases in food production in the past century, but, as the paper in PNAS points out, the repeated use of herbicides exerting strong selection pressure on crop weeds has led to more than 250 documented cases of herbicide resistance, and "this process is likely to accelerate with increased reliance on herbicides."

Glyphosate has been available since 1974, but to date only six cases of glyphosate resistance in plants have been reported out of the 250 documented cases of herbicide resistance. The makers of the best-known glyphosate herbicide developed RoundUp-Ready® canola, corn, cotton, soybeans and sugar beets – crop varieties that aren't harmed by glyphosate, which means it can be used to kill weeds and increase yields.

"Our interviews with farmers in the Southeast suggest that morning glories can tolerate applications of glyphosate," said Baucom, "and, in some cases, increasing concentrations of the herbicide have been required to control it."

Such an increase in tolerance to the chemical gives researchers a unique opportunity to study the evolutionary genetics of a novel trait and may help them and others slow the rate of evolution of tolerance in morning glories.

What Baucom and Mauricio found was that, in at least one natural population of morning glories they studied, there is a substantial genetic variation for tolerance, meaning that the "evolutionary door" is wide open. For evolution by natural selection to succeed, there must be genetic variation with a population and a significant selective force. This study is a case-in-point of evolution by selection – human-mediated evolution, similar to the evolution of bacteria resistant to antibiotics.

"Given the continued presence of glyphosate, the number of tolerant individuals should increase within the population over time," the scientists reported, "as might the overall level of tolerance of the population." The fact that glyphosate is a relatively recent tool in the fight against weeds led the scientists to conclude that the tolerance trait in this wild population was naturally occurring – not caused by use of the herbicide.

The presence of genetic variation, however, does not in itself guarantee that tolerance to glyphosate will evolve. The requirement also exists of "net selection" for tolerance, and it is acted upon by two components: fitness costs and benefits. The "benefit" of being tolerant must outweigh any sort of "cost" of being tolerant, much akin to the theory of economic cost/benefit models.

In the ecological realm, however, the production of offspring can be compared to making money. For example, in the face of glyphosate application, if the benefits of being able to tolerate the chemical outweigh the costs, then the tolerant individuals will produce offspring for future generations and the susceptible individuals will not. Costs are thought to be caused by diverting important nutrients and resources away from reproduction into the trait(s) conferring the ability to be tolerant. Costs are evident only in an environment in which the benefit of tolerance is not needed, that is, in an environment without glyphosate. Thus, if the benefits of tolerance outweigh the costs, then glyphosate-tolerant plants can increase in the population by the action of selection.

In fact, this research has shown that there is positive directional selection for tolerance to glyphosate, meaning that by applying glyphosate, those that are tolerant to the herbicide produce more seeds than those that are susceptible (given that susceptible individuals either die or produce almost no seed). Perhaps more key for the farmer, however, is the finding that in an environment devoid of glyphosate, tolerant families produce many fewer seeds or offspring than susceptible families. This is evidence of a fitness cost of tolerance, and this information can be used in managing or controlling the further evolution of tolerance in morning glories by arguing for not spraying RoundUp® in certain years. Since the issues are so complex, new strategies will have to be considered to control increasing numbers of glyphosate-tolerant varieties.

"Hers [Baucom's] is the first demonstration of a fitness cost of tolerance to glyphosate," said Mauricio. "This finding, along with an analysis suggesting a critical evolutionary threshold has been crossed, will be of broad interest to scientists and policymakers."

Morning glories are not at the level of such nuisance weeds as musk thistles in crops, but they are still a widespread problem for farmers. The new evidence for genetic variation of tolerance in morning glories, however, points toward a potential problem with no easy solutions.

"For glyphosate, such strategies could involve something as simple as periodically spraying with alternate herbicides, as long as there is little cross-tolerance with glyphosate," said the authors. "If, however, there is cross-tolerance with other causes of plant damage, such as hail, herbivores or pathogens, alternative spraying regimes may not be a viable mechanism for controlling the evolution of glyphosate tolerance."

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