Monsanto adds dicamba to its cache to counter weed threat

The US Department of Agriculture (USDA) in January approved the first genetically modified crops designed to tolerate the herbicide dicamba. The crops—cotton and soybean varieties—were developed by St. Louis–based Monsanto. The dicamba-resistant cotton was also engineered to tolerate the herbicide glufosinate, making it one of a slew of genetically modified crops tolerant to two or more herbicides approved by the USDA (**Table 1**). The company says the dicamba (3,6-dichloro-2-methoxybenzoic acid)-tolerant crops are being brought to market to counter the growing problem of weed resistance to glyphosate, the most commonly used herbicide. Some argue that this weed-management option, though welcome by growers, may not be enough to address increasingly difficult-to-control weeds.

Growers rapidly adopted the first crops genetically engineered to resist herbicides in the mid-1990s when they were introduced by Monsanto and other seed companies. Most of these first-generation crops were resistant to the herbicide glyphosate, marketed as Roundup. It was a novel, easy and effective way to control weeds. Farmers could spray glyphosate on fields planted with glyphosate-tolerant crops, killing only the weeds and leaving the crops unharmed. "The technology was just too good," says Stanley Culpepper, an extension weed scientist at the University of Georgia College of Agricultural and Environmental Sciences in Tifton. "We got caught up in it—we all did."

As a result, some growers relied on the herbicide exclusively, and weeds all over the world developed resistance to it—a well-documented problem that Monsanto has acknowledged (*Nat. Biotechnol.* **28**, 537–538, 2010). Glyphosate-resistant Palmer amaranth (*Amaranthus palmeri*), an extremely fast-growing species, for example, is a major nuisance in Georgia. "We are hand weeding," says Culpepper. "We need new tools to help us."

The largest seed companies—Monsanto, Dow of Indianapolis, DuPont Pioneer of Johnston, Iowa, Syngenta of Basel, and Bayer CropScience of Monheim, Germany—are stacking traits to address the problem. They are engineering crops to be tolerant to two or more kinds of herbicides, such as glufosinate, 2, 4-D and hydroxyphenylpyruvate dioxygenase (HPPD) inhibitors, in different combinations. Monsanto's newly approved dicamba- and glufosinate-tolerant cotton is "one tool" to add to a grower's arsenal, and will likely "help some growers in some areas, but not growers in other areas," says Culpepper. The cotton contains a demethylase gene from *Stenotrophomonas maltophilia* that expresses a dicamba monooxygenase (DMO) protein to confer tolerance to dicamba herbicide. DMO protein rapidly demethylates dicamba to the herbicidally inactive metabolite 3,6-dichlorosalicylic acid. The dicamba tolerance trait in Monsanto's soybeans was conferred with a similar mode of action.

But it's only a matter of time before weeds will also become resistant to the companion herbicides of the new tools, say some scientists. In fact, there are some weeds, like waterhemp, that have already demonstrated ability to evolve resistance to dicamba, 2,4-D and HPPD—the companion herbicides for the recently approved stacked herbicide-tolerant crops, says Michael Owen, a university professor of agronomy at Iowa State University in Ames.

The key to combatting weed resistance is stewardship, robust agricultural management decisions and a diversity of tactics, says Owen. Monsanto says it has corrected the errors it made with glyphosate. "In general, the industry['s] and farmers' approach to weed management has been different for quite some time," says Danielle Stuart, a spokesperson for Monsanto. Stuart says the company encourages growers to use diversified weed management practices, and in 2008 put in place a cost-incentive program for cotton farmers to that end. The program was expanded in 2011 to include corn and soybean growers.

Monsanto is still awaiting a green light from the US Environmental Protection Agency (EPA) to commercialize dicamba. Monsanto has said that its dicamba-tolerant crops will likely increase the herbicide's use—a concern to environmental and consumer health groups. The potential for herbicide drift to neighboring fields is also a concern, particularly for growers of organic and specialty crops.

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Table 1 Stacked crops tolerant to two or more herbicides in the US

USDA Petition (application) number	Applicant	Crop	Event	USDA approval status	Companion herbicide registered by EPA for commercial use?	On the market?
13-262-01p	Dow	Cotton	2,4-D, glufosinate-tolerant	Pending	No	No
12-185-01p	Monsanto	Cotton	Dicamba, glufosinate-tolerant	Approved January 20, 2015	No	No
12-215-01p	Bayer/Syngenta	Soybean	HPPD, glufosinate-tolerant	Approved July 18, 2014	HPPD, no; glufosinate, yes	No
11-234-01p	Dow	Soybean	2,4-D, glyphosate and glufosinate-tolerant	Approved September 22, 2014	Yes	Seed production in progress for future commercialization
09-349-01	Dow	Soybean	2,4-D, glufosinate-tolerant	Approved September 22, 2014	Yes	No
09-328-01p	Bayer, M.S. Technologies (West Point, Iowa)	Soybean	Glyphosate, isoxaflutole-tolerant	Approved August 21, 2013	Glyphosate, yes; isoxaflutole, no	No
09-233-01p	Dow	Corn	2,4-D, ACCase-inhibitor-tolerant	Approved September 22, 2014	2,4-D combo with glyphosate, yes; ACCase-inhibitor, no	Corn undergoing stewarded introduction
07-152-01p	DuPont Pioneer	Corn	Glyphosate, imidazolinone-tolerant	Approved December 9, 2009	Yes	No
06-271-01p	DuPont Pioneer	Soybean	Glyphosate, acetolactate synthase-tolerant	Approved July 24, 2008	Yes	No

Glyphosate tolerance in some crops has been introduced by conventional crossing. 2,4-D, dichlorophenoxyacetic acid; HPPD, hydroxyphenylpyruvate dioxygenase; ACCase, acetyl-CoA carboxylase.