Using ecology and technology to Control Weeds

Modern agriculture relies on many chemicals to produce the food and animal feed demanded by a growing human population. Unfortunately, the use of chemical herbicides has resulted in some weed populations becoming resistant. Much like antibiotic resistance in the medical field has led some to fear a future where a simple infection can be deadly, there is concern that herbicides will become ineffective against common agricultural weeds.

The best way to preserve the effectiveness of herbicides is to use them less by either rotating chemical modes of action or relying instead on other management options. Widespread use of herbicide is a strong selective pressure on weed populations. Susceptible plants die off quickly, leaving those with resistance behind. If all that remains are resistant phenotypes, their offspring are likely to carry the trait. A few resistant plants that survive and breed can quickly repopulate the area.

Herbicide resistance was first documented in the 1950s, but the problem has been growing. The U.S. has more herbicide-resistant weeds than any other country (161) as documented by the International Survey of Herbicide Resistance in Weeds. This is likely due to the high proportion of herbicide-resistant crops planted since the 1990s. However, the U.S. is not alone; globally, there are 254 weed species across 70 countries with documented cases of herbicide resistance, and some are resistant to multiple herbicides.

Farmers cannot count on the development of new chemicals, either. There have been no new advances in the chemical modes of action in herbicides brought to market in more than 30 years. Because of this, farmers need to maintain the effectiveness of the chemical herbicides that they currently have access to, by using them less and combating weeds with alterna-
tive strategies. These strategies range from using management techniques developed before chemical herbicides were available as well as new technologies. Of course, these methods may be slightly less effective, challenging to implement at large scales, or simply take more time and money—making it hard to change farming practices.

Ecological Approaches

Farming at all scales, from home gardens to industrial agriculture, can reduce herbicide use by taking a diverse approach to weed control. Todd Gaines, a Molecular Weed Scientist at Colorado State University, says an “herbicide-only syndrome” has developed in farming. When developing weed management plans, herbicide has become the first line of defense. Gaines says there is a “need for more diversity in weed management,” including the use of cover crops as mulches and reducing weed seed sources.

Organic farming systems have a variety of weed control methods such as mulches and other physical barriers, hand weeding, and using cultivators to kill emerging weeds. These approaches can be more time and labor intensive, which is part of the reason organic produce fetches a premium price. Eric Gallandt, Professor of Weed Ecology at the University of Maine, describes organic farmers using the “many little hammers” approach to weed control. The phrase, coined by Gallandt and Matt Liebman, describes managing weeds using multiple stresses.

“Instead of solely focusing on killing weed seedlings, the biology and ecology of targeted species guide management strategies to deplete the weed seed bank, improve the crop competitive ability, and avoid proliferation of difficult-to-manage species,” Gallandt explains.

One important management strategy is to keep weed populations from increasing by focusing on seeds and the seed bank. Gallandt describes the seed bank in the same way you would think about your checking account, with deposits and withdrawals over time. For either your bank account or the seed bank, the fastest way to reach a zero balance is to keep making withdrawals without ever making a deposit. Farmers can draw down a seed bank by letting seeds sprout (withdrawing seeds) and destroying these individuals before they reach reproductive maturity (depositing new seeds). Of course, a field will never really reach a zero balance. Seeds can lay dormant in the soil for many years, or be moved by equipment and animals, so farmers need to continuously monitor fields and remove weeds even when they have significantly reduced a population.

Not all weed problems can be controlled through seed bank management. Weedy species that are long lived and spread belowground through rhizomes, like Johnsongrass, require a different approach for non-herbicide removal. While farmers may avoid disking a patch of Johnsongrass, which will spread rhizomes, and therefore, the problem across the field, disking can also be part of a management plan for rhizomatous weeds. Disking or hoeing will kill the aboveground parts of the plant and break up the roots, forcing the plant to use the stored energy to sprout. Continued treatment of the area, through disking or mowing, would continue to draw down stored resources, eventually killing the plant. However, this approach takes time and requires a plan and commitment to management to keep the problem from getting worse.

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Harnessing Inhibitors

Some home gardeners learn a hard lesson about what lives in the soil when their heirloom tomatoes become sickly and fail to produce fruit. If planted in the same spot year after year, fungi, nematodes, and bacteria that damage tomatoes can build up in the soil. To avoid this, gardeners should avoid planting tomatoes in the same spot year after year. Crop rotations to avoid harmful soil microbes are a way to benefit crops, but the concept of using soil microbes to inhibit the growth of weeds also has potential.

Bioherbicides, which use soil microorganisms to control weeds, are an alternative to chemical herbicides. Some bioherbicides are commercially available but not used as widely has chemical herbicides. Jenny Kao-Kniffin, an Associate Professor in the Department of Horticulture at Cornell University, is investigating management techniques that can increase the weed-suppressive activities of microbes. “It’s not necessarily a change in the composition of microorganisms, but instead, it could be a modification of their function,” she says.

One way Kao-Kniffin is looking to develop bioherbicides is to encourage soil microbes to compete with weeds for the nitrogen and phosphorus in the soil. “We are attempting to help crops get a head start in growing by delaying weed emergence early in the season via microbial capture and retention of nitrogen that reduces the growth of nitrogen-sensitive weeds that compete for nitrogen,” Kao-Kniffin says. This research requires understanding both the cash crops and weed species. There is also potential to identify and isolate weed-suppressing compounds produced by soil microbes, which could then be added to fields as bioherbicides.

While the use of microbes is an alternative to chemicals, solely relying upon one of these methods would result in the same problems of weed species developing resistance. “We need a multi-disciplinary team of investigators to come up with creative and radical ideas to overcome serious management problems,” Kao-Kniffin says, “[that can] bring together ideas and approaches across disciplines in synergistic ways to tackle this looming problem of increased herbicide resistance.”

Technology

There are other advances in equipment that could drastically change the approach to weed control. A recent story that appeared on the ASA, CSSA, and SSSA websites (e.g., see www.crops.org/science-news/dry-weeds-keep-crops) describes the use of a propane-fueled flame weeder. The flame weeder applies high heat to weeds, drying out the tissue and killing the plant without the need for chemical applications.

Weed-killing robots may also play a role. The Tertill, developed in part by those behind the Roomba, had a successful Kickstarter campaign, and units are scheduled to ship this summer. The robot is a small, solar-powered, four-wheel-drive weed whacker. The unit does daily patrols, clipping any small plants that it drives over. The Tertill will not damage desired vegetables once they grow over a specific height, and small transplants can be protected using barriers. Some of the drawback to the unit are that it...
can get stuck in mud, on large rocks, or in holes, and it is most effective in areas up to 100 ft². However, being marketed as a time saver that spends each day patrolling for new weeds, it obviously has high appeal for home gardeners.

Gallandt sees the potential for robotic weeders in the future. “It remains to be seen what the ‘ideal’ weeding robot will look like,” he says. “It could be an autonomous tractor with a very wide, camera-guided weeder, with hoes or flames that selectively target intra-row weeds.” Alternatively, robotic weeders may stay small like the Tertill. As the technology advances, units may be capable of covering larger areas and communicating with other units to ensure that an entire field is patrolled. It may seem far-fetched, but this technology may come to market faster than new chemical herbicides.

Many of these non-herbicide management techniques may be difficult or cost prohibitive to do on a large scale for crops like corn and soybeans. However, the development of alternatives to chemical weed control needs to be happening before chemical options are rendered useless due to herbicide resistance. Changing the system, and solving the “herbicide-only syndrome,” will require greater economic analysis and the development of decision-making tools to aid farmers.

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June 2018  CSA News  7