Back to Basics

Breeding plants for organic agriculture

by Nancy Maddox

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Around 10,000 BC, the dawn of the Agricultural Revolution, human societies began domesticating wild plants. For the next 12,000 years, farming relied exclusively on natural inputs, such as animal manure and compost.

The first synthetic fertilizers and pesticides were developed only about 100 years ago but quickly became mainstays of “conventional” farming. In 1992, virtually all of the 460 million acres of U.S. cropland—all but 0.001%—were conventionally managed.

About this same time, however, a new trend emerged, marked by growing interest in traditional and innovative farming practices that invigorate the soil, without resorting to most synthetic chemicals. The Organic Foods Production Act of 1990 laid out the principles of this new “organic” farming and authorized the USDA to establish a program that would identify acceptable organic production inputs and certify farms meeting the agency’s standards. In 2000, the USDA published its final rule for the National Organic Program, which became operational in 2002.

Now, with increased momentum from the farm-to-fork movement and environmentally aware consumers, the organic food industry is going mainstream. Three out of four conventional grocery stores today offer organic products, according to the USDA. And the amount of cropland devoted to organic agriculture rose from just 403,400 acres in 1992 to roughly 3.1 million acres in 2011. In 2014, organic food sales reached an estimated $35 billion.

In fact, organic foods constitute the fastest-growing agricultural sector. This thin slice of the market has enjoyed a double-digit increase in consumer demand every year for more than a decade, notwithstanding an economic recession and a hefty price differential between conventional and organic. In December 2012, for example, a 25-lb sack of loose conventional carrots had a wholesale price of $12.50 in the Atlanta market. A comparable bag of organic carrots, meanwhile, sold for $24.50.

As says Martin Diffley, an organic farmer and farming consultant based in Farmington, MN, “The organic market is not as big [as the conventional market], but very loyal.”

These market incentives notwithstanding, however, adoption of organic farming is still relatively rare. Just 1% of U.S. farms are USDA organic-certified, and these select few are disproportionately small farms, with annual sales under $250,000.

As it turns out, going back to basics—farming in accord with nature and eschewing many of the practices of conventional agriculture—is not so easy after all. And one of the biggest challenges organic farmers face is simply finding locally adapted plant varieties that will thrive under organic farming conditions.

Creating ‘Optimal Genetics’ for Organic Farming

Organic farmers face a unique set of challenges and thus need crop plants with a unique blend of traits. To fight disease and pests in the absence of chemical supports, for example, organic plant varieties should have strong natural resistance to insects and pathogens. They should also grow quickly and densely to outcompete weeds. Of course, researchers have long sought to enhance such traits in plants bred for large conventional farms with uniform production inputs; however, these conventional varieties are not ideal for the diverse growing conditions found on organic farms. And, in fact, some farmers, like Diffley, believe that modern agriculture has unintentionally caused the decline of certain vital attributes.

“Think of it this way,” he says. “The organic system is the system that has existed since cultivation began. But with the advent of chemical dependence, the plants have lost their ability to source nutrients, to put down roots. The chemicals were easy to access. And that attribute was lost.”

Moreover, while organic consumers are willing to pay a premium, they want high-quality produce, with something to set it apart from commodity-type selections. “Consumers are looking for really novel traits—unique flavor profiles, unique colors, different culinary attributes,” says ASA member Erin Silva, an assistant professor of plant pathology and organic cropping specialist at the University of Wisconsin–Madison. “Organic farmers are better able to carve out a niche in the marketplace by growing varieties with these unique characteristics.”

Of course, farmers don’t generally bed out leafy plants; they sow seeds. And finding organic seed can be a daunting task.

Kristina Hubbard, communications director for the non-profit Organic Seed Alliance (OSA), says, “We recently heard from one organic seed company that there are so few organic seed suppliers that a single crop failure can mean the complete absence of that variety for the year because, at times, there are no backup sources.”

Under USDA regulations, organic-certified farmers can resort to untreated, conventional, non-genetically modified seed if appropriate organic seed is unavailable for a particular crop. But, says Hubbard, conventional seed is often “bred and produced in chemical-intensive systems that are in conflict with organic principles.” This provenance, she adds, “means [organic] farmers probably don’t get the optimal genetics for their unique production systems.”

Indeed, a 2009 OSA survey of organic farmers found that only 20% of the 1,027 respondents had been us-
ing 100% organic seed for at least the previous three years.

An added challenge of organic seed production is that sometimes the dynamics of the organic marketplace create demand for smaller quantities of seed but more diverse varieties. So, if seed producers are trying to grow smaller quantities, they need to make sure it’s not cross-contaminated with any other varieties of the same crop that they might be growing. This way, farmers who eventually buy the seed can be confident they’re getting what they paid for, Silva explains. But “it’s logistically more difficult than if you’re just growing acres and acres of one variety.”

Marko Colby, who owns 29-ac Midori Farm on Washington’s Olympic Peninsula, uses about half conventional and half organic-certified seed because many of his preferred crop varieties are unavailable in organic-certified seed. Although organic seed is becoming easier to obtain today, he says, historically it has been prone to greater variability than conventional seed, stemming from an admixture of genes from wild plant populations and a poor selection process. “A lot of [organic seed] used to come from small farms with limited technical information,” Colby says. “That is changing now.”

Given the limited choice of good-quality organic seed, both Colby and Diffley have joined a small cadre of organic growers who are, quite literally, taking matters into their own hands and working with formal breeders to create the resources they need to sustain their farming operations.

The metrics for success vary from crop to crop—the deep green hue of a spinach leaf, sweet balanced flavor of an ear of corn, or the strong early vigor of a carrot plant, for example. But ultimately, success boils down to one thing: an unblemished, flavorful crop that meets consumer demands.

Who Gets Kissed?

Breeding plants, Diffley says, is like raising children: “Some people are cut out for it, and some are not.” Count him in the first category. The Minnesota farmer is among the proud parents of a new, open-pollinated sweet corn variety adapted for his cool, northern soils, called “Who Gets Kissed?”

With its yellow and white kernels, the variety is named for a game played at corn husking bees of old, where communities gathered to husk corn and dance. When a person found an ear with all red kernels—or a “pokeberry ear”—they could choose one person among the group to kiss. Released last December, the plant was the result of a participatory breeding program involving Diffley, OSA, and UW-Madison sweet corn breeder Bill Tracy.

Tracy, an ASA and CSSA member, says conventional sweet corn seeds are generally treated with fungicides, and maybe insecticides, before they’re sold. “And, of course, that gives those seeds an advantages in terms of germinating and being able to grow rapidly and fight off pests during germination,” he says. In contrast, “Who Gets Kissed”
fends for itself; the variety has natural resistance to some of the most common corn ailments, including the soil-borne fungal diseases, smut and rust.

Weeds are another matter. To outcompete the herbaceous pests, “rapid germination and rapid growth are important,” Tracy says. “You want to shade the ground, form a canopy quickly.”

There are different ways to do this, he adds. “With sweet corn, you can pack many plants per acre, but you get smaller ears, and if ears get too small, they’re not marketable.” Other strategies are varying the leaf morphology or varying plant height, taller plants being better weed competitors than shorter plants.

In developing the weed-fighting ability of “Who Gets Kissed,” the breeders either exposed the plants to weed pressure or planted them at high density and then selected the star performers. Says Tracy, “We let the plants tell us which trait is best.”

Diffley points out other considerations. The flavor of the ear shouldn’t be based solely on sugar content, but on an adequate mix of sugar and starch in the kernel. He also looks for commonality or homogenization to a degree, so that the plants and ears are uniform enough that they’re dependable for point-of-purchase and similar enough to represent that variety.

Finally, the perfect organic sweet corn must source nutrients efficiently and display a general, overall vigor. With all of these traits, it is safe to say that “Who Gets Kissed” is no meek maize.

And because the variety is open-pollinated, Diffley says, “We’re talking about the corn delivering the goods and then growers having the option to grow it out as seed, based on their own criteria.”

Three states to the west of Diffley, Colby has been working with OSA on a similar project to breed organic spinach suitable for Pacific Northwest growing conditions. He joined the project after coming across some sample seed that performed so well in his fields that he was eager to help perfect it. The resulting variety, “Abundant Bloomsdale,” is slated for commercial release in 2015 after a decade of fine-tuning on eight organic farms.

During the first season of the effort, Colby explains, the team planted a large amount of the spinach seed and then looked for several preferred traits: plants with dark green, savoy leaves; plants with more round leaves than arrow leaves; and ones that held their leaves upright and away from soil-borne pathogens. Another characteristic they sought was general health and vigor.

Colby then saved seed from about 40 standout plants and sowed hundreds of seeds from each mother plant. Since spinach is wind-pollinated, it was easy to let all those strains cross again, after pulling the poorest performers. The next year, he repeated the process.

Making a Better Cotton Plant

Organic agriculture is not limited to edible produce. ASA and CSSA member Jane Dever specializes in another kind of crop altogether—cotton. Dever has been breeding cotton plants for years, first as a breeding and trait development manager with Bayer CropScience and, since 2008, as a professor at Texas A&M AgriLife Research and Extension Center in Lubbock. While her early career focused on genetically modifying the plants, today she strives to maintain the purity of new, improved organic varieties. It isn’t easy.

Although more than 95% of U.S. organic cotton is grown on the Texas High Plains, Dever says, “We’re 15,000 ac [of organic cotton] in the middle of 3.5 million ac of conventional cotton.” To assure strict segregation, Texas’s organic growers use physical distance and “trap crops,” such as grain or sorghum, to isolate and surround seed production areas.

Yet, despite the hassle of plant segregation, West Texas is a great place to grow organic cotton. The region has very low insect pressure, reasonably low weed pressure, and a good marketing cooperative. But the real advantage, Dever says, is that “we have a killing frost.”

Freezing temperatures stand in for the chemical defoliants conventional growers use to rid cotton plants of leafy vegetation. “If you don’t get the green leaves to drop before mechanical harvesting,” Dever says, “they can stain the cotton.” Even worse, once the cotton is compressed into “big bread loaves” for easy transporting, any green organic matter buried within can heat up and ignite.

Next year, Dever and colleagues will release some of their first new organic varieties, carefully bred to achieve several marks of merit:

- High fiber retention in the boll ("so the cotton won’t fall out on the ground before the freeze").
- High fruiting-to-vegetative ratio (to minimize leaves and assure “plants don’t get real limby”—thereby negating the need for conventional growth regulators).
- Consistently good fiber length and strength. (“This is really important because we have such a small volume that you would interrupt your market without consistent quality.”)
- Drought and salt tolerance.
- A thicker leaf cuticle to resist early pests, such as thrips. (“We were able to provide the same protection with the varieties alone as with an organic-approved pesticide, such as Spinosad.”)

And “last but not least,” Dever says, organic cotton plants must produce seeds with a nutrition profile suitable for dairy cows: “Our dairy cows are locavores; they eat the organic cotton seed we produce here.”
Colby says, “We did a lot of improvement. It’s a really nice spinach—super tasty and disease resistant. That’s what got us into breeding,” he adds. “We can impact genetics within a couple generations [to get a plant] that will grow well in our particular microclimate. It’s an art that has been perfected over hundreds or thousands of years.”

Silva, at UW-Madison, is trying to work the same magic with carrots, one of the largest organic vegetable crops nationally, but also one of the hardest to cultivate organically. Working with unadapted wild species collected from across the globe by USDA researchers, Silva has found great diversity in early emergence, canopy closure, and the amount of canopy—all critical attributes for weed control.

“Particularly, weed management is difficult,” Silva says. “There are some organic insecticides and fungicides but no organic herbicides.”

The carrot-breeding effort is still young, but Silva is optimistic. “If we can continue to demonstrate we do have effective methods of managing weeds and insects, conventional farmers would be more interested in transitioning to organic, at least for a portion of their acreage,” she says.

Dever is also quick to acknowledge the added benefits of organic farming, including greater worker safety and ecosystem enhancements. “I don’t necessarily condone all the economic studies comparing farming systems,” she says, “because that’s not why these guys have gained by farming this way. So, even though organic is less than 1% [of all U.S. cropland], the knowledge these guys have gained by farming this way has a tremendous value.”

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Colby echoes that thought. “Organic farming has a host of challenges,” he says. “But I think the joys of the successes we do have, and the ability to see the soil improving over time and see the plants responding to that healthy soil and having our hands in part of the creation of what we’re doing, well, I’m pretty happy about it every day.”

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