The Alluring Genesis of Seed

by Hannah Traggis

The Mystery of Seed

This was the goal of the leaf and the root. For this did the blossom burn its hour. This little grain is the ultimate fruit. This is the awesome vessel of power. For this is the source of the root and the bud…. World unto world unto world remolded. This is the seed, compact of God. Wherein all mystery is enfolded.


There is a beauty and wonder in seeds, an enigmatic fertilization, a fascination full of hope and promise for the future. As I sit here, futilely trying to resist the urge to place “just one more” order for seeds online, having already just come home from Agway with a few packets tucked into my bag of seed potatoes, I am inspired to consider for the umpteenth time, what is the irresistible allure of seeds. What makes me scour page upon page of seed catalog after seed catalog, 30 or more in a season – what fuels my desire to collect, grow and possess seeds. Continually searching for new seedpeople, I travel across the country just to gather with fellow seed enthusiasts. My Instagram feed is riddled with seed savers, seed breeders, seed historians and seed librarians, my bookshelves safeguard a collection spanning 1000s of years of human connection to seed and the many uses of plants to nourish, cloth, protect, and enrich our lives.

Take a moment and ponder with me, what is a seed? Why would you read this article about seeds? Where does your imagination take you when you gaze down at that handfull of seeds just before sowing them gently in the warm spring soil? Where did they come from? How many lives interwoven with the past of that seed and the decisions made that collectively and ultimately created that seed? That very seed there in your hand! What will happen to it once it leaves your hand?

Through botanical and ethnobotanical texts, college and post-graduate degrees, conferences, symposia, and endless discussions with fellow seed addictions, I have shared this fascination and sought answers to these questions for decades. Since I was 11 and opened my very first Seeds Blüm catalog, exactly shared with me by my mother, not only seed, but its stunning diversity enchanted me. I was immediately taken in by the concept that each seed carries a history with it and that the potential within a seed can be handed down -- potential to respond, acclimate and survive to the right conditions to sprout and reveal the potential held within – potential to respond, acclimate and survive to the right conditions to sprout and reveal the potential held within our growing seed collection.

Seed diversity… some seeds wear their diversity on their coats brilliantly patterned with a myriad of colors while others hide their light inside, waiting for just the right conditions to sprout and reveal the potential held within -- potential to respond, acclimate and survive to the fickle environment in which they may sprout.

Fascinated, captivated, and enchanted by seeds, my lifelong journey with seeds and plants has lead me to the deep belief that seeds are our agricultural history and the fundamental unit of our food system. They carry and define our cultural identities as our ancestors evolved alongside the foods they domesticated and cultivated. Every seed holds the potential to continue that journey of co-evolution with humans. With a deeper understanding of how seed is created, we can all continue to engage in that co-evolutionary dance that has been man’s greatest privilege since the onset of civilization – a dance that has driven the very rise of civilization!

What is a seed? Plants reproduce themselves in many ways including asexually via cloning themselves. In flowering plants, however, biodiversity is increased much faster through sexual reproduction and the complex mixing of genetic material that is contained in the resultant seed. To begin to understand how this process may play out on our farms, let’s start with a simple question: what is a seed? It is symbol of hope, poetic muse, primary component of human food worldwide, extreme survivalist, and protector and progenitor of its species. Botanical-ly, a seed is a complex structure containing a dormant embryo that is capable of enduring extended periods of inhospitable conditions that its parents possibly could not. When conditions improve, the embryo awakes from its state of suspended animation, germinates and grows into a new plant, sometimes years after its parents are dead and gone. Seeds are also a mode of travel for otherwise stationary plants. They can stick to the fur coats of animals, float on tiny parachutes, catapult several feet from ejecting seed pods, voyage the world’s ocean currents, or take a roller-coaster ride through an animal’s digestive tract.

There are three important structures that allow a seed to carry out these critical functions of dormancy, travel, reawakening, and germination. The three es (continued on page B 2)
Working with Nature to Design Food

by Jack Kittredge

As you will learn if you read this issue, the historical role of farmers has not been just to provide food for humanity. They also, by selecting plants to provide seed for next year, that seed, and growing it out in populations that enable crossings, are inherently partners with nature in the design of the germplasm that will be our food in the future.

For thousands of years this has been an almost unconscious aspect of good farming. Only in the last century or so has supplying seed become a separate business in developed countries. We justify handing off this function on the basis of convenience and a faith in the benefits of science and technology. But we are now seeing the price to be paid for losing control of seed.

Food plants are not being designed for nutrition or even flavor so much as for commercial qualities such as shelf life, cosmetic appeal, and size. Varieties perfect for our small farms and challenging climate are disappearing because the volume of their sales does not justify the costs involved for large marketers. And science and technology are now baring their teeth as patents, licenses, and lawsuits are increasingly coming between farmers and their craft.

Food is necessary for the embryonic plant as it awakens and resumes physiological function within the seed. To germinate, the seed coat splits and the radicle is the first structure to grow out of the seed, into the dark soil. Once the radicle takes hold and anchors the seed, the hypocotyl elongates and the plumule emerges from the soil. All of this happens before the tiny plant is able to photosynthesize. The seed’s stored food is all the energy the seed has to get its very first leaves into the sun. Food is stored either as endosperm surrounding the embryo, or within the cotyledons or ‘seed leaves’. The type of food energy stored varies between seed type. Corn, and many other small grains, for instance, primarily stores starch, while oilseeds such as flax, sunflower, or canola predominantly store oil and fat. Legumes are high in protein.

The seed coat protects the embryo and food source from environmental elements. It is often leathery and capable of expanding when the seed is ready to germinate. Many seeds can persist for years in the soil without dying because of the testa’s ability to protect its precious contents so completely. It would be wrong to say one of these structures is more important than another, because if the seed fails and the seed will likely die or suffer severely reduced vigor. Collectively, they are a biomechanical masterpiece.

How is a seed formed?

The genes that control the development of a branch and the structure that develops and holds flowers, is called an ‘inflorescence’. There are many types of inflorescences. Flowers can be arranged in many ways on the inflorescence stem that is called a ‘peduncle’. This includes a solitary flower at the end of a single peduncle and multiple flowers arranged on panicles including racemes, spikes, umbels, and capitula. The arrangement of flowers on an inflorescence affects, in part, how those flowers can or cannot cross pollinate and mate.

The peduncle terminates in a swollen tip called a receptacle and the flower sits atop that. The flower itself begins formation hidden inside a bud and is comprised of four separate whorls of modified leaves: sepals, petals, stamens, and pistil, each with an important function. The sepals are the most leaf-like in both form and color. They are the green layer you see on the outside of a flower bud and their function is to protect the bud as the young flower parts form within. The petals form just inside the sepals and their main function is to attract pollinators. Petals also often contain nectaries, small glands that produce nectar that serves as a reward for visiting pollinators. Nectaries can be produced on other parts of the flower and plant, but are most often associated with the petals.

The last two whorls in a complete flower are the separate male and female organs. The stamen, produced just inside the petals, is comprised of a filament and an anther and is the male sex organ of a plant. The filament contains vascular tissues and carries nutrients to the anther, inside which thousands of pollen grains are formed. Pollen is a tiny, autonomous structure capable of living outside of the parent plant and is composed of three cells, two of sperm and one, the ‘tube cell’, is a cell that will ultimately form a pollen tube.

Nestled and protected within all of these layers is the mature female portion of the plant, the pistil. The pistil consists of a stigma, style, and an ovary (also often called a carpel). A carpel can contain one or several carpels fused together. The stigma is the outer most portion of the pistil and is the site upon which a pollen grain lands. When the flower is mature, the surface of the stigma is said to be receptive and is sticky which makes picking up pollen easier. The stigma reacts biochemically to pollen grains to determine if the pollen grain is compatible to mate with the flower or not. A potential barrier to fertilization is that under extreme heat and dry conditions the stigma of a mature flower may dry up making pollen recognition impossible. The style is specialized tissue that connects the stigma and ovary through which pollen tubes will grow. It is also thought to help the stigma determine pollen grain compatibility.

Located at the base of the pistil is the ovary, or gynoecium (the ‘female house’), containing several layers of maternal tissue. Deeply held and protected within the ovary are the ovules, complex structures that contain more layers of mother tissue and, ultimately, an embryo sac. The embryo sac contains the female sex cells, namely an egg and the ‘polar nuclei’. An ovary can contain one to several hundred ovules. It is noteworthy of mention that the multiple layers of protective tissue surrounding the ovules are an evolutionary development in the development of complex flowering land plants. This development ensures not only the long-term survival of the species, but its ability to disperse itself across diverse habitats and ecosystems.

Flowers can have all of these whorls (the sepals, petals, stamens, and pistils), or just a few of them. Flowers possessing all of these parts are said to be “complete”. Flowers missing one or more major parts are “incomplete”. Flowers can also be classified according to their sex. Some flowers are bisexual and contain both stamens and petals. Other flowers are male and do not contain a pistil. While still other flowers are female, and do not contain a stamen. Finally, some flowers are

(continued from page 1)

components of a seed are: the embryo; food storage; and a protective coat called the ‘testa’.

The embryo is the tiny dormant plant, complete with a nascent root, the ‘radicle’, and shoot, called the ‘plumule’. Connecting these is the ‘hypocotyl’, an embryonic stem that elongates and pushes the first leaves out of the ground after the radicle takes hold in the soil.

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A complete daffodil flower showing all four modified leaf whorls that comprise a flower. The sepals and petals, male stamen showing the filament and anther; and the female pistil showing the stigma, style, ovary, and ovules.
Botany of Seed Formation: Pollination

Plants have adapted diverse strategies to facilitate that union. Many involve the exploitation of animal accomplices by providing tasty and nutritious rewards such as nectar, or intoxicating scents to lure animals to the flower. Pollen that relies on being carried by animal counterparts is often large, sticky, and has appendages that help the pollen stick to the animal. Other plants rely only on the wind to carry pollen. This pollen is often smooth, tiny, and extremely light. The pollen of many wind-pollinated plants can travel up to 5 miles on a strong breeze. The delivery of pollen to the stigma is called pollination and is susceptible to many environmental factors that can thwart its completion.

Botany of Seed Formation: Fertilization

Now that the pollen grain has reached the female, the stigma must recognize it as compatible. This is a biochemical process and once successful, the pollen grain begins to hydrate and germinate taking up moisture from the surrounding environment. Healthy “viable” pollen can still be damaged by extreme heat and dry conditions, and die out. The stigma will open and the pollen is delivered to the ovary of the flower. Once inside the ovule, the pollen will begin to hydrate and the starch contained in the pollen will begin to convert into sugars, which will then be used to produce the embryo. A single pollen grain can produce many embryos, hence the need for self and cross-pollination for successful fertilization. The process of fertilization involves the union of the sperm with the egg to form a zygote.

Botany of Seed Formation: Pollen and Fruit Formation

After fertilization, the ovary of the flower will begin to swell and eventually become a fruit. The fruit contains the seeds, which are the reproductive units of the plant. The fruit protects the seeds from the elements and provides a means for dispersal. The fruit can be dry or fleshy, and there are many different types of fruits, each with its own unique characteristics.

Botany of Seed Formation: Seed Development

Once the ovary of the flower has been fertilized, the ovule will begin to develop into a seed. The ovule contains the egg and one or two polar nuclei. The egg is fertilized by a single sperm, and the polar nuclei are fertilized by a second sperm. The resulting zygote develops into an embryonic plant, and the two polar nuclei develop into the embryonic suspensor, which provides nutrients for the developing seed.

As each of the ovules is fertilized, they send signals to the surrounding ovary tissue to begin to change and develop into a fruit. While we often call these “vegetables”, botanically, any structure ripening from the flower is a fruit. Fruits serve many purposes, such as providing a means of dispersal, nourishment for birds and animals, and protection for the developing seeds.

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The vast majority of plants, however, reproduce via “cross-pollination” and are called “crossers”. Cross-pollinated plants suffer greatly when inbred, a condition known as “inbreeding depression”, exhibiting loss of vigor and often times early death. These plants must intermate and share pollen with a large population of its species and cultivar. Cross-pollinated plants rely on sex external to pollinators, whether insect or animal mediated or wind, and can have either perfect bisexual flowers or separate male and female flowers. If flowers are perfect, the plant employs a few methods to prevent self-pollination. One method blocks pollen recognition by the stigma. Another, blocks pollen tubes from delivering sperm to the ovule. A third method involves the anthers and stigmas of the same flowers maturing at different times so that when the stigma is receptive, the pollen from that flower is not viable and vice versa.

If the cross-pollinating plant has evolved to produce separate male and female flowers, there are also variations on that theme! In some plants, such as most cucurbits and corn, the male and female flowers are found on the same plant but in separate locations making a proximal barrier to self-pollination. Often, the male flowers form several days before the female flowers which further blocks the plant’s ability to pollinate itself which adds an additional, temporal barrier to self-pollination. These plants are called “monoecious” meaning “one house” that includes both male and female flowers.

Another condition is that of the male and female flowers born on separate plants entirely. Spinach is a common example and the male and female plants even look different. Pollen often needs to be carried quite a distance from the male plant to the female. These types of plants are called “dioecious”, meaning two houses, one for male flowers, and one for female. Dioecious plants require the greatest degree of cross-pollination to maintain healthy seed production. (continued on page B 30)
Reconnecting to an ancient tradition of plant improvement

Over the last century, we have not only lost valuable genetic diversity through modern agricultural practices, we have also lost much of the knowledge needed to steward our genetic resources. As farmers, gardeners, and plant enthusiasts, we all have an opportunity to shape sustainable agriculture in fundamental ways. By making new varieties available, we are able to give everyone new options.

Building a healthy, sustainable agriculture future requires farmer-centric seed systems at the regional level, where farmers and the communities they serve consciously choose which crop genetics they use, how they are maintained, and how these genetics are controlled. Done well, plant breeding can help ensure that we all control the seed we need. Breeding work can give us free access to genetic resources and the freedom to grow what we want.

All good farmers and gardeners who survived and flourished were, by necessity, plant breeders. They used observational skills to determine and select the best-adapted plants every year. This meant selecting the highest yielding, best tasting, and most disease-resistant plants. All of the heirloom crop varieties we know and enjoy today were developed over a long, rich period of our history, telling the tale of our plant breeding ancestors who were making selections and saving seed from the healthiest and most vigorous plants year after year. These farmers were constantly striving to improve varieties to better suit their needs, engaging in a constant dance of improvement and co-evolution with their food.

Modern farmers and gardeners who are choosing to produce and select crop varieties to flourish in their region are standing on the shoulders of the best plant breeders of the past who domesticated and continually improved our crop genetic resources.

There will always be a need to adapt new varieties to current challenges, such as climate change. Classical plant breeding allows us to select, adapt, and continually co-evolve with our food crops. This form of plant breeding is not to be viewed as “messing” with nature, and it is certainly not genetic engineering. The principles of evolution show us that there is always variation in biological populations, environmental conditions always change, and no biological entity ever stays the same in response to its environment. In other words, no organism remains static in nature. Selection pressure and change over time are inevitable. We advocate for an evolutionary breeding model that allows the varieties we use to be part of the sustainable agricultural systems we are pioneering.

This article gives some basic steps to get you started on your plant breeding journey, introducing how to choose varieties to start with and the steps to improve them. However, there is more than one lifetime worth of learning to experience in this path. If you want to go further, take a look at some of the references at the end of the article.

Determining traits

Knowing what you want is critical to getting what you want. The most successful breeding projects have clearly defined traits that are being selected for or against. Prior to starting the breeding effort, it is important to take the broadly defined goals and market criteria. What would this ideal variety look like? How would it perform? What traits would it need to have to be successful? What are the traits that are important to the farmer and marketplace?

Some examples of traits that you may want to select for include:

- Plant height
- Plant stature
- Days to maturity
- Harvestable yield
- Color
- Flavor
- Texture
- Storage life
- Seedling vigor
- Pest Resistance
- Disease Resistance

Prioritizing traits

Once you have compiled a list of traits, the next step is to prioritize them. In general, a breeding project should not attempt to actively select for more than five or six traits at any given time. There may be more than five traits that are important, but it’s not feasible to work on everything all at once. Also consider that some traits may be easily fixed, or “locked in,” by choosing parents that share these traits. In this case, effective selection may be achieved simply by throwing out a couple of off-type plants here and there.

Choosing parents

Germlasm is a general term that refers to the collection of genetic resources for a plant species. Varieties, landraces, collections, breeding lines, and unimproved material are all types of germplasm.

Essentially germplasm is any form of living tissue (e.g., seeds, cuttings, roots, and tubers) from which plants can be grown. Germlasm is the parental material used to begin your breeding work. Sourcing quality germplasm determines how easily and rapidly you will be able to develop your desired variety.

There are two main factors to consider when choosing germplasm:

- Quality: the germplasm should include elements of the ideal variety you are striving to produce
- Variability: the germplasm should have variation for the trait(s) you want to improve

Consider varieties that:

- Perform well in your target environment
- Are considered to be commercial standards
- Contain unique traits that you want to incorporate into your project

Many valuable varieties for breeding work can be found in the catalogs of domestic and international seed companies. However, be aware of legal protections on some varieties that restrict their use for breeding or limit what you can do with them in other ways. These protections include plant patents, utility patents, plant variety protection certificates, and licenses. You can find more information about these protections on eOrganic’s intellectual property protection page at http://www.extension.org/pages/18449. Always investigate your germplasm sources to ensure there are no legal restrictions on breeding.

Besides seed companies, you can also source germplasm from:

- Farmers
- Seed exchanges
- Germplasm Resource Information Network: http://www.ars-grin.gov/

Unless you are already familiar with the germplasm you want to use in your project, it is wise to conduct variety trials to evaluate the available sources of germplasm. A guide to conducting variety trials can be found on Organic Seed Alliance’s website at: http://www.seedalliance.org/Publications/.

Creating a breeding timeline

Step 1. Conduct variety trials to identify the best potential parental germplasm.

Before committing to a long-term breeding project, carefully evaluate potential parental germplasm. This evaluation typically takes the form of a variety trial. A variety trial is a systematic way to evaluate a set of varieties using good trial design.

The purpose of a trial design is to help minimize the environmental variation to ensure that the differences observed represent genetic differences between plants. For details on how to conduct variety trials refer to Organic Seed Alliance’s publication On-farm Variety Trials: A Guide for Organic Vegetable, Herb, and Flower Producers, which can be downloaded at: http://www.seedalliance.org/Publications/.

Step 2. If necessary, make crosses between parents. If adequate variation is present in a favorable existing variety, then no crosses are necessary.

To improve your population, some degree of variation for important traits is necessary. To have a variable population, you need to either start with germplasm that is variable for the traits you intend to improve, or you need to create variation by crossing two or more varieties together. These crosses can be made in a number of ways, depending on your goals and resources.

The Natural Farmer

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Getting Started with Plant Breeding

On Your Farm or in Your Garden

by Jared Zystro


http://www.extension.org/pages/18449. Always investigate your germplasm sources to ensure there are no legal restrictions on breeding.

http://www.ars-grin.gov/
Types of crosses:

Controlled pollinations: Plant breeding might evoke an image of breeders making controlled crosses, perhaps with tweezers, magnifying glasses, and small paper tubes. The general strategy will depend on whether the species you work with has perfect flowers or not. Perfect flowers have both male and female parts on the same flower. If the plant has perfect flowers, you will generally need to emasculate the female parent by removing the male stamen and then transfer pollen from the male parent. If the plant has only unisexual flowers – flowers that contain either all male or all female parts – there is no need to emasculate. You just transfer pollen from a male flower to a female flower. After pollinating, some sort of cover is often used to exclude other pollen from contaminating the cross.

Open pollinations: These crosses are also known as strain crosses or blind crosses, and are done by allowing one plant or a set of plants to cross with another plant or set of plants without making an attempt to ensure that pollen is only transferred between certain plants. This is accomplished by bringing all or parts of the plants together and allowing them to freely cross-pollinate. Outside pollen is excluded either by isolation distance or by caging the plants inside a structure that prevents insects and pollen from entering.

Hybrids: These varieties can be used as pre-made crosses, saving a step in the breeding process. Keep in mind, however, that most hybrids are made by crossing two narrowly selected inbred parents and therefore a population formed from a single hybrid will have comparatively little genetic diversity relative to one created from a strain or blind cross between open-pollinated varieties.

Step 3. If you are working with a cross-pollinating crop and you made crosses, allow the offspring to randomly mate for at least two or three generations while removing obvious undesirable plants. In the case of self-pollinated crops, allow the plants to naturally self-pollinate for at least two or three generations after the cross while removing undesirable plants.

Prior to selection, grow your new breeding population for a few generations, allowing the plant to flower and freely cross-pollinate. During this time, you may practice negative mass selection (selecting based on how individual plants look) to rogue out the worst performing plants.

It is tempting to begin intensive selection in the generation after your crosses are made, as plant breeding can be such a long process. However, we recommend that you do not skip this step. In cross-pollinated crops, allowing a few generations of random mating breaks up the linkage between genes. Simply stated, linkage refers to how genes in a plant will tend to travel together. For example, if you cross a tall plant with dark leaves with a short plant with light leaves, you’re more likely to get either a tall dark plant or a short light plant than you are to get a tall, light plant or short, dark plant. Random mating for a couple of generations allows the genes to shuffle and makes it more likely that you will see new combinations of genes in the population.

For self-pollinated crops, it is also valuable to wait for at least two or three generations before making any significant selections. The reason for this is different for self- and cross-pollinated crops. As described in the previous discussion of differences in genetic structures between cross- and self-pollinated crops, random mating and the breaking of linkage does not occur in self-pollinated crops. Instead, each plant derived from the offspring of a cross has the potential to become a separate, independent family line with unique combinations of fixed pairs of genes. As each of these lines continues to self-pollinate over the course of a few generations, each line will become more uniform and the differences between lines will become more obvious. It will be easier to make distinctions between families if sufficient time has passed to allow the families to essentially become fixed and distinct from one another.

Additionally, the more generations you spend improving the population by this gradual process (mass selection), the better the genetics of the population will be, and the more likely you will be successful in the later phases of breeding.

These generations will also give you a chance to get to know the population, to see what kinds of variation exist in it, and to evaluate what its strengths and flaws are. Use these years to refine your goals, traits of interest, and evaluation techniques. Remember, when practicing selection, make sure the field location represents the location you want to select for and is relatively uniform throughout.

Step 4. Grow a large population and save seed separately from individual plants. The seed from individual plants becomes families.

During this generation you will be selecting your best plants to serve as parents for families. Evaluate your plants multiple times throughout the season, considering the goals and traits you have prioritized. Since there may be some variation in the soil quality, weed pressures, and other factors in your field, select the best plants from all parts of the field equally. If all of the plants in one corner of your field look worse off than the rest, you still try to pick some of the best looking plants in that patch – those are plants that can survive under some environmental stress or potentially sub-optimal conditions.

If your crop is cross-pollinating and is a crop where you have an opportunity to evaluate and select the best plants before pollination occurs, you will make faster progress by removing all inferior plants from the field before pollination occurs. In this way, any cross-pollination that occurs will only be between the selected plants.

When you harvest seed from selected plants, put seed from each plant into a separate bag. The seed in each bag represents a family. Label each family with a unique number. Along with the number on each label, you may want to make notes about why you selected that plant. These plants will represent families for the next generation’s round of selection. In the case of cross-pollinated crops, try to save seed from at least 20 to 50 individual plants. In the case of self-pollinating crops, save seed from at least 30 to 100 plants.

Step 5. The following generation, grow family plots by planting each separate plot with seed harvested from an individual plant. Evaluate and select the best performing families.

This generation you will be looking at the progeny of your selected plants as families. In breeding terms, this is the process of family selection. This means you will plant seed from each plant that you selected in separate plots or rows, just as if you were conducting a trial, following the best practices of trial design as outlined in OSA’s On-farm Variety Trials: A Guide for Organic Vegetable, Herb, and Flower Producers.

Examine each plot as a whole. How does this family of related plants look? On average, which families look best given your goals and traits? Select the best families based on their overall quality, and eliminate the other families, preferably before they have a chance to cross-pollinate with the selected families. Look for families where at least 60 to 80% of the plants are acceptable.

Next, select the best plants within the best families. Aim to eliminate 30 to 40% of the plants within a family, keeping in mind the minimum population size you want to maintain to keep the population healthy.

Step 6. Harvest seed from the best plants within the best families.

At this point, save the seed from each family. In other words, combine the seed from all of the selected plants within each family so that you end up with a separate bag for each family.

Step 7. Repeat the process of growing and selecting family plots until you are satisfied with the performance of all selected families.

The following generation, continue to plant the selected families in separate plots and evaluate them again throughout the season. If, during the second round of evaluations, some of the families no longer seem acceptable, discard those families. Also eliminate all inferior plants within the selected families that you decide to carry on to the next generation.

Step 8. Once the selected families are all acceptable, combine the seed of these families together into a bulk population.

For these past few generations, you have been maintaining the population as a set of separate families. Once all of the remaining families meet your goals, you can combine them together to reform the population.

OSA’s Katie Miller evaluating carrot breeding families in El Centro, CA.
I hope that this brief introduction gives you some of the tools to think about developing your own unique varieties to meet your needs and the needs of your community. Below are some resources for further exploration.

**Further reading**


**Seed as a collective commons**

The principles of diversity, fairness, and shared rights are associated with the seed they’re buying or already using.

As an organic community, we have an opportunity – a responsibility – to create a different path of prosperity and food security – to further research, education, and innovation, and make advancements accessible to all.

In important ways these laws were about sowing seeds, literally and figuratively. The new infrastructure established through these laws aimed to expand U.S. agriculture for the sake of prosperity and food security – to further research, education, and innovation, and make advancements accessible to all.

By the end of the nineteenth century, a third of USDA’s budget was allocated for seed collection and distribution. The department encouraged farmers to try new crops and continued the practice of distributing free seed. And, thanks to the Morrill Act, states had a place in the plant sciences. Land grants largely focused on collecting seed and conducting research in areas that were not yet available to burgeoning private ventures.

Try to picture it: USDA freely distributing seed to farmers (at the time, half the population) not so much as a commodity but as an essential natural resource best managed in the hands of the people. The department understood that the nation’s growing (and now rich) crop diversity was a product of farmers serving as plant breeders in their own region. Their labor and land – and the knowledge base they built through experimenting, screening, and selecting – effectively adapted plants, some exotic, to regional agricultural ecosystems.

Meanwhile, land grant universities’ regional breeding programs gained momentum, providing new plant varieties to farmers. These public programs supported agriculture by increasing yields and developing a strong base of scientific knowledge in research facilities. Private companies emerged, but at their products were inferior in quality and quantity.

The private seed trade expanded, and organized efforts to confront their most formidable competitor at the time: the government. Congress shut down the USDA’s distribution of free seed in 1924 following lobbying by the seed trade. Over the decades that followed, the number of independent seed companies grew.

The political climate was such that lawmakers were facing heightened pressure throughout the twentieth century to create policies that protected investments in research and development. IP rights had been discussed for decades, and the first law to provide breeders some protection passed in 1930. Importantly, this law, the Plant Patent Act, excluded sexually reproducing plants as patentable subject matter, and only applied to asexual reproduction, such as grafting and cuttings.

In fact, Congress long argued that sexually reproducing plants shouldn’t be awarded utility patents – “patents for invention” – for fear of curtailing innovation, threatening the free exchange of seed, and increasing market concentration.

But the lobbying efforts of plant developers, including members of the seed trade, were eventually successful in convincing Congress that more protection was warranted. This came in the form of a “patent-like” protection under the Plant Variety Protection Act (PVP) of 1970. The law represented a compromise: Breeders had the exclusive right to propagate and market the variety for 20 years, but the law provided important exceptions: 1) other plant breeders can use protected varieties for breeding and research, and 2) farmers can save seed from protected varieties to replant on their own farm.

Although many breeders still use PVP protections today, Congress’ concerns regarding IP rights on plants have been realized – but not because of this law. At the turn of the twenty-first century, the Supreme Court upheld a case where the Patent and Trademark Office (PTO) awarded the first utility patent on a lifestyle. (The PTO had earlier refused to award this patent, but the U.S. Board of Patent Appeals and Interferences disagreed and granted it.)

Once the provider of free seed, the modern day PTO is responsible for setting a precedent that forever changed our access to, and relationship with, seed.
Owners of utility patents have far-reaching control over access to and use of their protected products. While the PVPA has exemptions for researchers and farmers, utility patents can be legally enforced to forbid access to protected seed for purposes of innovation as well as on-farm seed saving. Patents therefore remove valuable genetic material from the pool of seed that public breeders rely on for improving crops. What access breeders do have often hinges on restrictive licensing agreements (i.e., restrictions on how the seed can be used, what can be researched, and whether findings can be published).

Furthermore, patent owners can deny licensing agreements for strategic purposes to prevent competition. This in turn denies breeders from improving and expanding the plant genetics on which agriculture depends. Especially problematic is the increased trend in broad patents covering traits that also occur in nature and can be selected for through classical breeding methods, such as “red lettuce,” “brilliant white cauliflower,” and “heat tolerant broccoli.”

Utility patents are also commonly enforced to remove a farmer’s right to save and replant seed, the very practice that conserves and generates diversity of domesticated crops. By being forced to repurchase seed each year, farmers not only shoulder higher annual expenses, they lose the ability to adapt seed to regional climates, soils, and disease pressures.

The increase in IP rights has been coupled with a concurrent loss in growers’ knowledge and skills to keep seed diversity alive and co-evolving with human communities and climates.

In the seed sector, utility patents quickly led to increased concentration of financial and genetic resources. Transnational chemical and biotechnology firms entered the seed industry to capitalize off the new IP rights playing field. Their expansion of agricultural biotechnology, and the profits from their patented products, led to dozens of unchecked acquisitions and mergers.

Today, four seed companies now control more than 60% of the global market. These companies include Bayer (which recently acquired Monsanto), DowDuPont (a merger that resulted in the agricultural firm, Corteva), ChemChina (which recently acquired Syngenta), and BASF. Economists say that an industry has lost its competitive character when the concentration ratio of the top four firms is 40% or higher. The seed industry continues to exceed this benchmark not only across the entire global supply, but across crop types as well. For example, even before the Big 4 merged, three firms (Monsanto, Syngenta, and Vilmorin) controlled 60% of the global vegetable seed market.

History shows that seed industry consolidation leads to less choice and higher prices for farmers. These companies also aggressively protect their IP rights, which means less innovation and more restrictions on how seed is used and exchanged, including for seed saving and research purposes. These restrictions affect conventional and organic agriculture alike by making a large pool of plant genetics inaccessible to public researchers, farmers, and independent breeders, which in turn limits the diversity of seed in our landscapes and marketplace, and weakens our food security.

The extent of market concentration is most obvious when looking at biotechnology traits, namely Roundup Ready and Bt crops. Bayer’s (formerly Monsanto’s) genetically engineered (GE) traits are planted to nearly all U.S. corn, cotton, soybean, and sugar beet acreage. A number of patents are associated with these GE varieties (see Figure 1).

Today, many smaller companies cannot compete with large firms that have patented much of our crop genetics and sell only proprietary products. Licensing genetics from these firms is costly, creating a barrier to new private research firms. More than 200 independent seed companies have been lost over the last 20 years alone, including companies that were interested in organic and conventional (non-GE) seed. The result has been less competition and choice in the marketplace, and a lack of infrastructure to provide for the diverse and regional needs of farmers.

For example, Trisler Seeds, Inc., based in Fairmont, Illinois, is a well-established seed company with a 70-year history in seed corn. In 2006, Monsanto’s holding company, American Seed Incorporated (ASI) purchased Trisler, after which the diversity in seed options decreased dramatically. In 2004, Trisler offered 33 conventional (non-GE) corn varieties, about 40% of its seed corn platform. In the years following the acquisition, Trisler’s conventional (non-GE) corn options were cut by 91% even in light of a major resurgence in demand for non-GE corn and soybean. This decision was due to the increased cost of GE seed and herbicides, the emergence of glyphosate-resistant weeds, and premium prices paid for non-GE grain. Monsanto purchased Heritage Seeds, based in Reynolds, Indiana, the same year, in 2006, and eventually stopped selling non-GE varieties through this new acquisition altogether. Lewis Hybrids, an Illinois family business established in 1946, underwent similar shifts in catalogue offerings after it was acquired alongside Trisler and Heritage (see Figure 2).

Dicamba-resistant soybeans are a more recent example. Within three years of their introduction, these GE soybeans made up 60 – 75% of the soybean market. One interpretation of rapid adoption is demand. Another is lack of choice. In the case of Dicamba-resistant soybeans, the new trait began to dominate catalogues and farm fields, many farmers across the Midwest and Southern states chose to grow these varieties not because of superior performance or other production advantages, but out of fear. A class-action lawsuit underway is representing farmers who believe they have no choice to grow these varieties or they risk losing their soybean crops that don’t survive contact with Dicamba. Non-resistant varieties are easily damaged by this herbicide because it volatilizes and drifts.

The concerns are warranted: Dicamba drift affected approximately 3.6 million acres of soybeans in 2017. More than 1,000 farmers are currently suing Bayer for damage caused by Dicamba drift on account of this new chemical-seed package. And, as if organic and other non-GE grain growers didn’t have enough to worry about: Bayer is currently applying for government approval of Dicamba-resistant corn.
How do these trends in IP rights and concentration impact organic seed? Consolidation in the seed trade is as much about concentrated ownership of seed as it is about concentrated market power in the seed trade. One factor is that independent seed companies that don’t have the financial means for breeding programs heavily rely on licensing seed from bigger companies. For example, hybrid seed companies have become dependent on inbred lines produced by larger companies. These inbred lines can’t be treated with chemicals and ideally shouldn’t have the presence of GE traits.

But farmers, plant breeders, and seed companies are getting organized to both confront these troubling trends and find alternative paths. In 2016, the University of Wisconsin-Madison, in conjunction with the National Association of Plant Breeders, organized an Intellectual Property Rights for Public Plant Breeding Summit. The purpose of the summit was to identify mechanisms that facilitate investments in, and broader distribution of, publicly developed plant varieties. In other words, how can public breeding programs better ensure that farmers and the broader public benefit from tax-dollar investments and that these breeding programs remain viable? Best practices and policy recommendations have since been published at https://agronomy.wisc.edu/ipr-summit/.

Around the same time, a group of plant breeders, seed companies, academics, farmers, and nonprofits announced the Open Source Seed Initiative (OSSI). Inspired by the open source software movement, OSSI was created to “free the seed” – to create a protected commons. After finding it difficult to develop a practical and legally enforceable open-source license, the initiative instead published a list of terms that want to protect their reputation as a supplier of “clean” seed in a vulnerable position of risking litigation if they decide to test for detectable levels of GE traits illegally. The president of Albert Lea Seed House, Mac Ehrhardt, estimates that of more than 1,940 hybrid lines available, only 8% are available as non-GE line and in an untreated form (see Figure 3). Field corn is one of the most widely planted organic crops in the U.S. and yet choice in organic seed is limited due in part to lack of access to appropriate lines. This lack of access serves as a barrier for expanding choice in organic hybrid seed corn, since these inbred lines can’t be treated with chemicals and ideally shouldn’t have the presence of GE traits.

The pledge states: “You have the freedom to use these OSSI-Pledged seeds in any way you choose. In return, you pledge not to restrict others’ use of these seeds or their derivatives by patents or other means, and to include this Pledge with any transfer of these seeds or their derivatives.” OSSI has generated a lot of interest in the U.S. and abroad, and currently lists more than 400 varieties representing more than 40 crops on its website. Nonprofits and universities are also re-evaluating, and elevating, the role that fair licensing agreements can play in furthering open-source principles when developing new varieties. These agreements neither prohibit farmers from saving seed nor restrict breeders from using the seed for breeding or research purposes. Fair licenses can also generate income, where reasonable royalties provide a source of income to developers and fund research programs.

1. Educate yourself. There are numerous forms of IP used in the seed trade, and most are legally binding. A comparison of these IP tools is included in Figure 4.

2. Check variety descriptions in seed catalogues. Look for language or a symbol in a variety’s catalogue description that indicates if it’s a protected variety. For example, Fedco Seeds lists which varieties are covered by PVP certificates, or an OSSI pledge, or a host of other categories to guide your decision making.

3. Call your seed suppliers. If it’s unclear whether a variety you’re buying or already using has any IP rights associated with it, call the seed supplier to ask for this information and about what, if any, IP policies they hold as a company. As a customer, communicating your needs and concerns directly to your seed suppliers is the best way to let companies to respond to requests.
for more transparency. They may even start prioritizing varieties held in the public domain.

4. Read your seed packets and bags. Some seed packaging may have restrictions listed in fine print. Two decades ago, these licensing agreements on packaging — think of a shrinkwrap agreement on software — were only seen on bags of GE varieties of seed, such as Roundup Ready soybeans. Today, even non-GE crops sold by larger firms come with a "bag tag" that restricts seed saving and research, and delineates other egregious terms as well.

But not all IP is restrictive to managing seed as part of our commons. As one example, the breeding team at Organic Seed Alliance (OSA) co-released an organically bred sweet corn variety, "Who Gets Kissed?", in partnership with the University of Wisconsin-Madison and organic farmer Martin Diffley. The variety was initially released to High Mowing Organic Seeds under an exclusive three-year contract, which has now ended, and returned a royalty to collaborators. Furthermore, unlike restrictive forms of licensing agreements, this agreement did not restrict farmer or breeder rights. In fact, in conjunction with the variety’s release, OSA published an on-farm organic sweet corn breeding manual for farmers looking to save seed and make selections on sweet corn. The manual teaches farmers how to adapt this variety and other sweet corns to their specific climate, farm conditions, and market needs — skills that are especially important as our climates change. In other words, seed saving is encouraged!

OSA also released an organically bred spinach variety developed in partnership with eight organic farms on the Olympic Peninsula in Washington. "Abundant Bloomsdale" spinach is sold freely and other sweet corns to their specific climate, farm conditions, and market needs — skills that are especially important as our climates change. In other words, seed saving is encouraged!

Creating a path toward decentralization

All of us have a role to play in fostering more decentralized models for how seed is bred, produced, and distributed. From a policy standpoint, Congress should do away with utility patents to level the playing field and create structural changes to how seed is managed and shared. As discussed, the seed market is highly concentrated, as is the ownership of seed itself. The Department of Justice has abdicating its role in breaking up oligopolies power so it is up to the public to demand action and resist practices and companies that put the sustainability and security of our food and farming future at risk. Becoming educated on IP rights is one step in building a democratic seed system. Letting your seed suppliers know where you stand on restrictive IP tools is another one, and can ripple into a mighty wave of awareness and action that results in more seed remaining in our collective commons. Continuing to save, share, and sell seed in a way that supports access and fairness is a third way to participate in a seed system that is more just.

We, the people, hold the power. And we hold the power of people and plants to co-evolve in ways that generate more genetic and biological diversity, and allow us to adapt to a future that we can only try to predict. But to realize the full potential of our human-plant partnerships, we must create structural changes to how seed is managed and shared.

Seed is regarded as part of the collective commons for the past 10,000

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Turtle Tree: Seeds for Vibrant Living

by Lia Babitch

Turtle Tree Seed has been growing seeds in Copake, NY since 1998. In the early days, we grew nearly all of our own seed here, and we still grow most of it—well over 60% of our 300+ varieties. We choose which varieties we offer by trialing different varieties, and try to get seeds from as many reliable sources as possible in order to be able to grow to seed and offer the one which has been the best maintained. Not all seed is equal. We focus on open pollinated seeds, and because the breeding and monetary priorities of many larger seed companies often tend towards hybrids, many of the older open-pollinated varieties have fallen on hard times. Many have grown wild and uncared-for in large field seed growing where little or no selection was happening over generations.

As a small company, we can’t offer the breadth of variety that a larger company can, but what we can do to is to take care of the varieties entrusted to us, cleaning up varieties that have drifted from the original, tightening the uniformity of other varieties, and most importantly, control what we are selecting for. Some varieties will need intensive selection and breeding help throughout their life cycles and through many generations, while some better selected varieties may just need some basic roguing at a few critical growing moments to keep the variety energetic and true to type. Each variety we maintain becomes a friend. Through the years we get to know it, and work to allow it to express its best, truest individuality as a variety through our care and maintenance.

Sometimes we also work on breeding new varieties, such as our new Robbie’s Red tomato. This new variety was a surprise project that came out of a wild and woolly trial of a variety that had been poorly selected—one plant was extraordinary, with out-of-this-world tomato flavor—and so our breeding work began to help reveal that flavor and stabilize a population out of that original selection. A more planned and organized breeding project, which resulted in our Red Sunset onion, came from a wish to untangle a good open-pollinated round red storage onion from a hybrid. After 10 years, we finally have something that we’re pretty happy about, though of course work continues on both varieties—when does it not?

Another aspect that makes Turtle Tree unique is that we are an integral part of Camp Hill Village. One of the most wonderful things about being embedded in a Camphill community (for more info visit www.camphillvillage.org) is that we have a wide population of folks who are happy to do taste testing and kitchen trialing of our varieties. Over the years we’ve introduced variety trialing to our homes and kitchens as well as our gardens. While these can’t be as rigorous and scientific as the taste testing we do here, it does give a good snapshot into end-use, and how the different vegetables and herbs stand up to many different cooks and cooking methods.

Camphill Village is a place where people with developmental differences are living a life of dignity, equality and purpose. The mission of Camp Hill Village includes care of the earth and care for people who have vulnerabilities. Our inclusive team is made up of people with developmental challenges whose abilities are honored through our work, and who find meaning in the importance of growing and cleaning seeds that will touch the lives of many. Also joining us are young volunteers from the US and around the world who come to work with and learn from our team, as well as long-term volunteers and employees.

Turtle Tree Biodynamic Seed Initiative is part of a larger whole biodynamic farm organism, encompassing a small dairy for our own in-village use, several acres of vegetables, a 3 acre herb and healing plant garden which combines beauty with abundance, about 150 acres of pasture and over 400 acres of woodland and wetlands that we help maintain and preserve. Turtle Tree Seed provides an essential element to this farm organism - the ability to be self-sustaining in terms of seed, and the possibility for many plants to complete their life cycle on our farm from seed to seed. Our mission at Turtle Tree goes beyond growing, improving, and providing an outlet for carefully grown, selected and bred open-pollinated biodynamic and organic seeds, and improving and breeding organic/biodynamic systems-appropriate vegetable, herb and flower varieties. We are deeply aware that agriculture has the possibility to either harm or heal the earth, which is why we practice regenerative agriculture which sequesters carbon, maintains and expands diversity in the ecosystems on our farm, and provides for essential human needs without extractive, reductive farming practices.

Lia is the co-general manager and garden manager at Turtle Tree. She has been with Turtle Tree since 2009. She can be reached at lea@turtletreeseed.org

Organic Plant Breeding Yields Superior Varieties

by Kiki Hubbard, Organic Seed Alliance

Farmers looking for disease resistant cucurbits now have more choices thanks to the release of new cucumber and melon varieties by Cornell University, the result of years of research by public plant breeders and organic farmers. These varieties are a result of participatory breeding efforts focused on cucurbits most in need of improvement, and exhibit exceptional resistance to evolving diseases as well as production and culinary characteristics important to organic farmers.

“Our approach to plant breeding involves a close collaboration with farmers, regional seed compa- nies, and other researchers to test varieties in the environment of their intended use,” says Michael Mazourek with the Department of Plant Breeding and Genetics at Cornell University. “In the case of these cucurbit varieties, they were all bred with the needs of organic farmers in mind.” Pathogens emerge and evolve quickly, and breeders struggle to stay ahead with new resistant varieties. Downy mildew and bacterial wilt are two devastat- ing diseases that too often wipe out entire cucumber crops. While conventional cucumber growers rely on synthetic chemical inputs, such as neonicoti- noid seed treatments and sprays, organic growers don’t have (or want) that option and instead rely even more on protecting crops from the inside out: through plant genetics resistant to diseases. “The beauty of our success is that these high-yielding, disease-resistant varieties are as beneficial to conventional growers as they are to organic,” Mazourek adds.

The varieties now available were developed with support from the National Institute for Food and Agriculture’s Organic Research and Extension Initi- ative (OREI), housed within the US Department of Agriculture (USDA). Partnering with Cornell Uni- versity on the Eastern Sustainable Organic Cucurbit Research Project (ESOcuc) were Auburn University, North Carolina State University, and Organic Seed Alliance. Farmers, extension agents, and seed compa- nies along the East Coast also played an important role.

The four objectives of ESOcuc were to evaluate the most popular cucurbit varieties for yield and pest and disease resistance; breed improved varieties; examine on-farm management strategies to over- come environmental and economic challenges; and make data available to farmers through field days, webinars, and other resources.

New cucumber is already a commercial hit

Farmer-breeder Edmund Frost says he can’t keep up with the demand for seed that he grows and sells of DMR401, a downy-mildew resistant (DMR) slicing cucumber variety that was completed through ESO- cuc. Frost helped Mazourek test this variety and related DMR lines from Cornell on his farm for four years to collect data on how it compares to other commercial varieties on the market.

“There’s really nothing else like it,” says Frost, an organic farmer and researcher based in Louisiana, Vir-
Edmund Frost of Common Wealth Seed Growers gives a tour of his organic cucurbit plant breeding projects focused on downy mildew resistance.

When Zaid Kurdieh met Michael Mazourek at the Stone Barns Center for Food and Agriculture five years ago, the first thing out of his mouth was: “Michael, we need better cucumbers.” Thus began a breeding partnership that quickly turned into a breeding team.

Kurdieh is the operator of Norwich Meadows Farm, a breeding partnership that quickly turned into a breeding team. Mazourek›s breeding team has made swift progress growing to resist both diseases.

Downy mildew is also wiping out melons. ‘Trifecta’ was first released in 2015 and consistently ranked highest for yield, quality, and DMR in Cornell’s trials. ‘Trifecta’ melon lives up to its name

Downy mildew is also wiping out melons. ‘Trifecta’ was first released in 2015 and consistently ranked highest for yield, quality, and DMR in Cornell’s trials. The variety was named by Frost, who identified the variety as a standout among several experimental melon lines from Cornell, and was most excited about the variety’s ability to consistently rank high in three targeted breeding goals: yield, quality, and DMR.

“Among the best downy-mildew resistance we’ve seen,” says Mazourek. “We made it a priority to distribute the variety through organic seed companies operating in the Southeast because there is an urgency in the region for varieties that reliably demonstrate resistance.”

Frost first noticed the seedstock that became ‘Trifecta’ for its eating quality in 2012 trials at his farm. In 2014, Frost received a grant from the Sustainable Agriculture Research and Education (SARE) program, administered by the USDA, to test melon, cucumber and squash varieties in late-planted conditions when downy mildew is most intense. ‘Trifecta’ again stood out for its excellent eating quality and yield – even under levels of DM pressure that defied most commercial melon varieties. The variety also exhibited good bacterial wilt resistance in the trial, and has done so in several trials Frost has conducted since then.

Frost recently received a grant from the Organic Farming Research Foundation to continue work on bacterial wilt and downy mildew resistance in cucumber and muskmelon seedstocks, including new slicing and pickling cucumber varieties he is developing to resist both diseases.

‘Trifecta’ is currently available for sale through Common Wealth Seed Growers and Southern Exposure Seed Exchange.

Organic research investments yield big impacts

As mentioned, ESOCuc is funded through the USDA’s competitive grant program focused on organic agriculture, the Organic Research and Extension Initiative (OREI). Organic plant breeding relies heavily on the OREI program, which is reauthorized as part of the farm bill every five years. Fortunately, in December 2018, Congress not only reauthorized OREI as part of the farm bill but they more than doubled the amount of funding available for organic research. Over the course of the next farm bill, OREI funding will increase from $20 million in 2019 to $50 million by 2023. The importance of these research dollars to the growth and success of organic agriculture cannot be overstated.

“So little public breeding underway is focused on the types of organic crops and varieties that are grown by promotional farmers,” Mazourek echoes his sentiment, pointing to the results these collaborations yield in the form of superior varieties now available to farmers.

“Of all our successes with DMR are owed to farmerinput,” says Mazourek. “We took moderately resistant material that we had at Cornell, moderately resistant material identified by organic farmers, and people are seeing the literal cross-pollination of these partnerships in our DMR varieties.”

Meeting the needs of high tunnel producers

In some cases, Mazourek explains, private funds have followed public investment. One example is the Clif Bar Family Foundation, which awarded a Seed Matters fellowship to Cornell PhD candidate Lauren Brzozowski. This fellowship allowed her to work on DMR401 until it was ready for the marketplace.

DMR401 is now available for purchase through Common Wealth Seed Growers, Southern Exposure Seed Exchange, and High Mowing Organic Seeds.

Organic plant breeders rely on neonicotinoid seed treatments and sprays to control the disease but fungicides are expensive and not always effective, as fungicide resistance can also emerge with the disease. Neonicotinoids are the most widely used pesticide and frequently make headlines because of growing concerns about their harmful impact on insect pollinators. Certified organic growers aren’t allowed to use synthetic chemicals like neonicos to manage pests and diseases.

Kurdieh grows cucumbers in high tunnels, 10-acres worth, which can make managing pests and diseases more challenging. Controlling cucumber beetles is particularly important as they transmit bacterial wilt. Mazourek explains that there is a lot of water moving through the plant and the bacteria ends up clogging the vascular system, killing the plants.

Conventional growers rely on neonicotinoid seed treatments and sprays to control the disease but fungicides are expensive and not always effective, as fungicide resistance can also emerge with the disease. Neonicotinoids are the most widely used pesticide and frequently make headlines because of growing concerns about their harmful impact on insect pollinators. Certified organic growers aren’t allowed to use synthetic chemicals like neonicos to manage pests and diseases.

Mazourek echoes this sentiment, pointing to the results these collaborations yield in the form of superior varieties now available to farmers.

“Of all our successes with DMR are owed to farmerinput,” says Mazourek. “We took moderately resistant material that we had at Cornell, moderately resistant material identified by organic farmers, and people are seeing the literal cross-pollination of these partnerships in our DMR varieties.”
Hamilton and D’Artagnan: A tale of two plant breeding projects

by Jason Cavatorta with Derek Cavatorta

Years ago, I bought an interesting-looking melon from a street vendor in Paris and tasted and tested for the first time the exotic, intoxicating flavor of the Charentais. Around the same time back home in his Massachusetts garden, my twin brother was tending a patch of his favorite crop: butternut squash. These actions were the inspiration for two plant breeding projects focused on improving the flavor of the foods that we grow and eat.

Why Undertake a Plant Breeding Project?

For most people who really enjoy a particular fruit or vegetable, it is enough to purchase one from the grocery store or local farmer and savor eating it. Others, in order to get improved quality and to participate more fully in the experience, grow their own in their garden and may even save the seeds of their favorite heirloom for next year. I see plant breeding as taking this process a step further, or maybe even several steps. To develop a new variety tends to escalate with the time, effort, and many years or more to complete – and the anticipation and gratification - a typical plant breeding project takes to add a bit of warning. Plant breeding can help her to produce for the benefit of mankind centuries, once said, “What a joy life is when you help. Luther Burbank, the famed Massachusetts-Importantly, plant breeding can be a lot of fun as developing and becoming stewards of our own new plant breeds. By crossing two existing cultivars together. The primary parental plants should be chosen to contain characteristics that you would like to combine together, such as different flavors, shapes, maturity, colors, disease resistances, etc. After this initial cross, multiple generations of planting, pollination, selection and seed saving are performed in the attempt to identify and stabilize the new variety you have envisioned.

The methodologies used to make pollinations vary widely between different crops, and there are several resources that do a good job explaining the finer points of each species. Butternut squash (Cucurbita moschata) and Charentais melon (Cucumis melo) are both members of the Cucurbitaceae Family and are outcrossing species – that is, their floral biology is vital before you begin, because all new plant breeding projects typically begin the same way by crossing two existing cultivars together. The original parental plants should be chosen to contain characteristics that you would like to combine together, such as different flavors, shapes, maturity, colors, disease resistances, etc. After this initial cross, multiple generations of planting, pollination, selection and seed saving are performed in the attempt to identify and stabilize the new variety you have envisioned.

The methodologies used to make pollinations vary widely between different crops, and there are several resources that do a good job explaining the finer points of each species. Butternut squash (Cucurbita moschata) and Charentais melon (Cucumis melo) are both members of the Cucurbitaceae Family and are outcrossing species – that is, their floral biology tends to promote pollination between plants as opposed to individual plants pollinating themselves. This means that unless steps are taken to prevent it, a flowering butternut plant may be pollinated by any other butternut plant in the vicinity. This can be a problem if you are trying to select and stabilize a particular set of characteristics because your plants may be pollinated by undesirable individuals. In order to control pollination, two things must occur. First, bee pollinators must be prevented from visiting your flowers. This can be achieved by securing the flowers closed the day before they open up. This can be done by excluding pollinators by doing your work in a greenhouse. Second, pollen from the desired plant (which may or may not be the same plant that is receiving the pollen) must be delivered by hand to the awaiting flower. The butternut squash, to me, is a quintessentially Yankee crop. It is a humble, respectable vegetable. It is solid and dense - a hardy, steadfast fruit that waits patiently on the vine until the gardener has time to bring in the harvest. Butternut squash are put away at summer’s end and reemerge from the cellar when the nights are cold and the days are short as a winsome reminder of the summer sun. It rarely takes center stage on the kitchen table but adds a savory-sweet accompaniment to hearty winter meals.

The butternut squash has been a staple in my brother Derek’s Massachusetts garden for many years. By the 2014 season he had settled on a commonly-grown powdery mildew resistant F1 hybrid as his preferred variety and decided to try his hand at developing his own open-pollinated version. The fairly simple idea of this project was to “dehybridize” his favorite butternut hybrid – that is, to develop a stable, open-pollinated cultivar by inbreeding while selecting for, and possibly improving on, the flavor and disease resistance of the starting hybrid. This methodology is a great way for a beginning plant breeder to get started, and a more detailed description of the process can be found in Carol Deppe’s book Breed Your Own Vegetable Varieties (2000). F1 hybrid cultivars are the result of crossing two butternut lines together, so the first step of making an initial cross pollination had already been performed. Consequently, all that was required in the first season was to grow out a crop of the hybrid cultivar without any other butternuts in the area. Simple enough. Plants of a hybrid variety are nearly genetically identical to each other, so it didn’t matter which plant(s) contributed the pollen. At the end of the season, we extracted seeds from the fruit and put them away until the spring.

The seeds harvested from the F1 hybrid cultivar make up the F2 generation. This is an exciting stage because all of the genetic differences that exist between the starting parental plants have been recombed and shuffled like a deck of cards. Consequently, each F2 plant is a genetically distinct individual. The F2 plants were grown out in Derek’s 2015 garden – which can only fit about 25 butternut...
plants. That year, every plant in the garden was pollinated to itself. Squash plants are monocious, meaning there are female flowers and male flowers on the same plant. To pollinate a squash plant to itself requires securing the flowers closed prior to opening using a twist tie or other method, and returning the next day to deliver the pollen between flowers. This must be done on every plant at flowering stage before you know which among them will produce desirable fruit. After pollination was completed, the plants were monitored for disease resistance to powdery mildew and attractive fruit shape. The selected fruit were put down cellar until Christmas time, when we made another round of selection based on how well they stored. For the last stage of selection, we relied solely on a taste test.

This was the fun part. Each fruit was labeled individually and the blossom end of the fruit, which contained the seeds, was set aside while the rest of the squash was cooked in the oven. We then sat down with a group of friends and family and tasted each butternut fruit, like wine tasters in Napa Valley, carefully noting on paper the texture qualities, flesh color, and assigning a flavor rating. At the end of the tasting, the notes were compiled and the winning fruit was selected. Of course, the seeds from that fruit were the ones chosen to be planted out the following year.

In the summer of 2016 the F3 generation, which came from the best F2 fruit, was grown in the garden. This time, because the individual plants were more closely related than the previous year, there was less variability between them. We decided to allow these plants to open-pollinate each other to prevent too much inbreeding and to avoid having to make time-consuming hand pollinations. Again, selections were made in the garden for disease resistance, fruit shape, and yield. Again, selected fruit were stored in the fall and selected for flavor.

The seeds from the best two squash were planted out in the summer of 2017. This process was repeated a final time in 2018. By this season, we were happy with the results: a uniform, medium-sized butternut with dark orange flesh, great flavor, good storage, and resistance to powdery mildew. The variety was named ‘Hamilton’ after the town in Massachusetts where it was developed – a nod to the famous ‘Waltham’ butternut of Waltham, Mass. The variety was named ‘Hamilton’ after the town in Massachusetts where it was developed – a nod to the famous ‘Waltham’ butternut of Waltham, Mass.

Development of ‘D’Artagnan’ Charentais Melon

The Charentais melon is the dramatic, epicurean cousin of the butternut squash. A Charentais melon shouts its presence with a fragrant, mushy aroma that quickly fills a room and cannot be ignored. The fruit is soft and sweet and must be eaten shortly after picking. It is a summer fling, a fleeting indulgence, and is unavailable outside of harvest season. It is a dessert unto itself and, even when indulgence, and is unavailable outside of harvest season. It is a summer flirtation, a fleeting fruit is soft and sweet and must be eaten shortly after picking. It is a summer flirtation, a fleeting fruit is soft and sweet and must be eaten shortly after picking. It is a summer flirtation, a fleeting fruit is soft and sweet and must be eaten shortly after picking.

The Three Musketeers, Dumas, in addition to being one of my favorite authors, had his own obsession with the Charentais melon. In 1864 he donated a copy of all of his published works to the town of Cavillon, France in exchange for an annuity of 12 melons each year.

In the early spring of 2018, more than half a decade after I’d eaten my first Charentais, I sent seeds of ‘D’Artagnan’ to a horticulturist in the South of France. In July I traveled there to see the trial, timing the trip to coincide with “La Fete du Melon” harvest festival. My brother Derek joined me on the trip. On a sun-drenched morning we visited the melon farmer in the production area south of Nimes.

These new experimental hybrids were grown out with farmers in multiple locations over two years to see how they performed under different growing conditions. They were grown in New England, Florida, Oregon, and Washington State. One of the most enjoyable steps for me is visiting the different growing regions to evaluate the fruit at harvest. Walking, knife in hand, through a field with my notebook, stopping to look, feel, smell, and taste each one is a lot of fun. Knowing the history behind each line, the years of growing them out, pollinating, extracting seeds, replanting, etc. adds to the excitement as you see how they combine with each other. There are always a lot of surprises at this stage, as it can be difficult to predict which crosses will make the best hybrid and often the parental characteristics combine in unexpected ways. The best approach is to make many F1 hybrid crosses and evaluate how they perform under many growing environments over multiple years.

During the trialing process I was looking primarily for the one that had the best flavor and yield. My hope for this variety is that it will be a sort of ambassador to help popularize Charentais in the United States, so it also had to have the classic size, shape, and color. After two years of testing in multiple growing regions I was able to narrow it down to my favorite hybrid. I named the variety ‘D’Artagnan’ after Alexandre Dumas’s character in The Three Musketeers.

To develop inbred lines that are uniformly high and stable typically takes about eight generations of inbreeding. After years of work and intensive selection, I developed a parental line that had all the desirable characteristics, most of them derived by crossing Charentais and American cantaloupes, that I was happy with. I was ready to make hybrids with the flavorful heirloom that had been waiting for its partner all this time. The heirloom variety was crossed to all nine new breeding lines to make nine new F1 cultivars with the hope that, in at least one of these combinations, the desirable characteristics of each parent would be contained in the hybrid between them.

During later generations I worked with two talented college student interns to verify the disease resistance by challenging my plants with fungal pathogens. After obtaining fungal spores from the USDA and growing them in an incubator, we inoculated the melon plants and noted which came from the best F2 fruit, was grown in the garden. This time, because the individual plants were more closely related than the previous year, there was less variability between them. We decided to allow these plants to open-pollinate each other to prevent too much inbreeding and to avoid having to make time-consuming hand pollinations. Again, selections were made in the garden for disease resistance, fruit shape, and yield. Again, selected fruit were stored in the fall and selected for flavor. The seeds from the best two squash were planted out the summer of 2017. This process was repeated a final time in 2018. By this season, we were happy with the results: a uniform, medium-sized butternut with dark orange flesh, great flavor, good storage, and resistance to powdery mildew. The variety was named ‘Hamilton’ after the town in Massachusetts where it was developed – a nod to the famous ‘Waltham’ butternut of Waltham, Mass. The variety was named ‘Hamilton’ after the town in Massachusetts where it was developed – a nod to the famous ‘Waltham’ butternut of Waltham, Mass.

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Raising My Own Varieties of Landrace Seed

by Joseph Lofthouse

In a quest to obtain more reliability, better flavors and nutrition, and higher productivity, I have been growing my own genetically-diverse, locally-adapted varieties for the past decade. That allows me to select for great tasting varieties that thrive on my farm with its unique climate, pests, soil, microbes, customers, and farmer habits.

By growing genetically-diverse landrace varieties I am able to get out of the way and let the intelligence of the plants solve problems that other farmers might be trying to solve using labor or materials. Not only do I save money by not purchasing seeds, I’m saving on other input costs like fertilizer and sprays. I taste every fruit before saving seeds from it. In doing so, I am selecting for flavors and aromas that are beloved by my community, thus increasing sales and enjoyment.

When I was buying seed from commercial sources, the seed was not locally-adapted to my ecosystem. Buying seeds from a glitzy catalog based on nothing more than a glib description resulted in failure rates of around 50% to 95%. When I grow my own seed, I know that the parents did well enough on my farm to make seeds. That’s a huge step forward in being able to rely on the productivity of my crops. Some species, there is a labor cost to growing one’s own seed, but the way I look at it, growing seeds is like growing money.

I call my method of seed saving landrace farming. Growers that want to sound avant-garde might call it evolutionary plant breeding. My Darwinian pals call it survival of the fittest. My definition of a landrace is a very genetically-diverse crop that has grown in the same place long enough to become part of the local ecosystem and cultural heritage.

To me, one of the most pleasant aspects of landrace seed saving is that because I am tasting every plant in every generation I am able to select for flavors, textures, and smells that are super pleasing to me as a primate animal. While I haven’t verified it in a laboratory, I suspect that foods that taste better are inherently more nutritious. Fruits that are higher in beta-carotene taste better to me. I can see beta-carotene in squash and muskmelons, so when I select for better taste, I am also inadvertently selecting for deeper more vibrant colors. I don’t like bitterness in cucumbers or lettuce, therefore I save seeds from plants that taste less bitter to me. My customers love me for it.

I believe that how a food tastes is due to many different processes in the plant, the ecosystem, and my body, being summed up into the final taste profile. Plants that are growing better on my farm tend to taste better to me than plants that are struggling to survive. By selecting for plants that are more tolerant of the local bugs, soils, climate, and farmer habits, it seems to me like I am also selecting for better taste.

My first exposure to landrace growing was a variety of sweet corn named Astronomy Domine which was developed by Alan Bishop of Pekin, Indiana. He allowed around 200 varieties of heirloom and hybrid corn to promiscuously cross-pollinate. The resulting population was a delightful mix of colors, textures, flavors, and plant types. I fell in love with it, and with the idea of landrace farming. Some of the plants only grew a few feet tall in my garden, and got eaten by pheasants. Some plants were too long season. I saved seeds from what survived, and what I loved. I replanted. I love colored corn, and I love shorter season crops. There was enough genetic diversity in the original population that I could easily select for bright colors in the sweet corn stage, and for quicker maturity. The cobs are multi-colored, adding lots of different phytotoxins to my diet.

When I first started landrace farming, I followed my training as a scientist, and embarked on a path of keeping elaborate pedigrees and saving thousands of packets of seeds from all sorts of different parents. I planted out fruit-to-row sibling group trials. I quickly found myself overwhelmed. Therefore, I looked to ancient history for inspiration. It seems like every domesticated species that I grow was originally developed by illiterate plant breeders. They couldn’t write, they didn’t know about DNA, and yet they developed sophisticated varieties. After some years of struggle about the genetics of landrace plant breeding, I have reduced it to a simple mantra: Offspring tend to resemble their parents and grandparents. The corollary of that is that if two great varieties cross-pollinate they tend to produce great offspring.

My current strategy is to limit record keeping to a phenotypic description of what the mother plant(s) were like. An example would be “Long-necked moschata”. For many crops, I keep only one jar of seeds per landrace variety. I decide how much seed I need for sharing, planting, and seed bank, and I keep that quantity of seed on hand. When fresh seed is available, I fill the storage container with about 2/3 new seed, and about 1/3 old seed. The excess seed is eaten by people or animals. By keeping some of the older seed around, I am hedging against one unusual growing season dramatically shifting the genetics away from the mean, and I am holding onto more genetic diversity.

The first landrace development project that I was exposed to used hundreds of varieties of sweet corn. More recently, I have had good results starting with 3 to 5 varieties. My basic strategy is to plant several varieties close together and allow them to promiscuously cross-pollinate as much as they will. I live in a difficult climate for many species. So the first year it is common to have a very high percentage of new varieties fail to make seeds. That’s where survival of the fittest comes in. A plant has to make seeds or contribute pollen before it can get incorporated into a breeding project on my farm.

I save seeds from what thrives for me, and what I love, and replant them. Year after year, I continue selecting for better flavors, higher nutrition, better productivity, etc. I select for traits that are beloved by my community. I am currently selecting for tomatoes that people are describing as “guava”, “fermenty”, “tropical”, “fruity”, “sweet”. I select for traits that are easier for me as a farmer. For example, while many farmers put in tremendous labor and materials to trellis their tomatoes, I avoid that labor.

The first landrace that I grew was Astronomy Domine sweet corn, developed by Alan Bishop of Pekin, Indiana.
by growing tomatoes sprawling on the ground. By doing so, I am selecting for tomatoes that grow well on my farm, even though the irrigation water splashes soil and it’s associated diseases onto them. I discovered after some years that I had inadvertently been selecting for a vine type that keeps the fruits off the ground. That is advantageous because it keeps the fruit cleaner. I didn’t intend to do that selection, it happened accidentally because I had been saving seeds from cleaner fruits, and the plants had enough diversity of stem types to satisfy my unconscious desire for clean fruits. That makes my life as a farmer easier.

I think of the third year as the magical year. By then, the combination of natural and farmer-directed selection has done a pretty good job of selecting for plants that thrive on my farm. Crops that are mostly out-crossing tend to become genetically-diverse and locally-adapted quicker than the mostly inbreeding crops. The mostly out-crossing species like corn, squash, and brassicas are playing the genetic lottery at high speed, so they are quick to adapt to new growing conditions. The mostly inbreeding species like lettuce, beans, peas are slower to adapt to local conditions, because they rarely cross-pollinate.

Careful observation to save seeds from the occasional naturally occurring cross in an inbreeding species can really speed up the process of local adaptation. For example, common beans are a species that are mostly self-pollinating most of the time. The natural cross-pollination rate is perhaps 1 in 200 at my place, or as much as 5% in farms with lots of pollinators. My beans aren’t crossing much, so the varieties tend to stagnate. However, by paying close attention I am able to identify new hybrids every year. I then plant them in a special place so that I can watch them and save more seed from them. The benefit of growing out the hybrids is that the genetics are rearranging themselves into lots of new patterns and it provides more opportunities to find varieties that thrive on my farm.

Another quick and easy way to get started with landrace farming is to import a genetically-diverse landrace from elsewhere. It won’t be locally adapted, but with so much genetic diversity something may feel really at home on my farm.

As an example: I have fond memories of my grandfather growing runner beans. I tried growing them too. Year after year, I bought a new variety of runner beans from a catalog and planted them. They didn’t make seeds. I think that my climate is too arid and too hot for them to do well. Then, a friend sent me landrace runner bean seed. A number of varieties had been promiscuously cross-pollinating on her farm. Therefore, it was like each seed was a new unique variety. Some of them grew great for me, and formed the foundation of my runner bean breeding project.

One of the joys of landrace farming is that I can save seed without caring much about isolation, or purity. A winter squash is a winter squash. As long as it tastes great, I don’t care what shape it is, or what color. I like to keep the sweet peppers separate from the hot peppers, so I practice some isolation, but it’s not the crazy-making isolation of the heirloom purists, who use every trick known to humanity to keep “open pollinated” varieties from being open to crossing. I often plant small quantities of new varieties next to my landraces. If I like them, I add them to the landrace. If I don’t like them, then maybe they contributed some pollen. I like small amounts of stray pollen. It adds diversity to my landraces.

On my farm, I encourage “promiscuous pollination” at every opportunity. It seems to me like varieties are stronger when their genetics are able to rearrange themselves routinely.

Tomatoes went through a number of genetic bottlenecks when they were domesticated. At each bottleneck they lost genetic diversity. Perhaps during the bottlenecks their accustomed pollinators didn’t make the trip with them, so self-pollination was favored. Perhaps people selected for inbreeding flowers instead of types that are more cross-pollinating. Modern sensibilities about heirloom preservation and keeping seed from crossing lead to further selection for ‘selfing’, and limited their genetic diversity even more. Each loss of genetic diversity can be likened to losing a piece of the intelligence about how to deal with problems that the plant might face.

I am currently engaged in a tomato-breeding project to undo that loss of diversity. I want my tomatoes to regain the intelligence they had before domestication. I am developing a variety of tomatoes that is self-incompatible. They are 100% out-crossing. Thus every seed is a unique F1 hybrid in every generation. Each seed is a new variety of tomato. The genetics are rapidly rearranging themselves in each generation rather than stagnating. That will make it trivial to throw hundreds of thousands of unique genetic combinations against problems like blights, mildews,rots, insects, etc. Thus we can allow the intelligence of a highly diverse tomato variety to solve those sorts of problems for itself. Along the way, we are likely to find astonishing flavors and aromas.

Muskmelons were the first variety that I bred specifically for my farm. Our valley is high in the mountains, the nights are cold, the season is short. Crops like melons that love the heat struggle here. Over several years, another farmer and I planted many dozens of varieties of melons. Most of them failed spectacularly. In the early years a few produced a few immature fruits, with some viable seeds. We saved and replanted the seeds from those that survived, and within a few years, we could reliably grow melons. Lots of melons, that got ripe weeks before the fall frosts arrive. I was so enamored with the first few landraces that I grew that I converted every species on my farm into modern landraces. I love the feedback from my customers when they say things like, “This is the first time I have been able to grow a muskmelon since I moved to the valley.”

Joseph Lofthouse is a subsistence farmer who grew up and still farms in northern Utah on the family farm that was settled by his ggg-grandmother. Growing conditions in that location are very challenging for many warmth-loving crops, so he became a plant breeder to select for varieties that can thrive in spite of the difficult growing conditions. Joseph shares his modern landrace varieties via a seed catalog reachable at http://garden.lofthouse.com/seed-list.phtml

Leaf diversity among tomato plants descended from crosses between wild and domestic tomatoes.

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Overcoming Bolero

by Petra Page-Mann

Nathaniel Thompson of Remembrance Farm grows 100 acres of biodynamic vegetables in the Finger Lakes of New York, including about 7 acres of carrots each season largely for his winter CSA. Over the years he hastrial ed dozens and dozens of varieties, hunting for that holy grail of vigor, storage and sweetness. He has found none that compare to Bolero, especially in the vigor department, which makes all the difference, especially at scale.

"Even after years of trials, my biodynamic farm is still dependent on this chemical, conventional seed," explained Nathaniel. And he isn’t alone. Bolero is grown on tens of thousands of acres around the world, in both conventional and organic fields alike. In 2015, the French multinational Vilmorin, who bred and produces Bolero, announced it would never release the F1 as an organic seed. "After years, I was finally going crazy."

Nathaniel approached us here at Fruition Seeds. We focus on regional adaptation as well as organics and we love to collaborate broadly with all stakeholders in the food system, from farmers to universities to foodbanks and everything in between. We had helped Nathaniel develop select strains of hyper-petalled, super colorful calendula for his salad mixes and a super-frilled, cold-tolerant Red Russian kale to increase his production in both spring and fall. Could we de-hybridize Bolero, as well?

The day Nathaniel asked us to de-hybridize Bolero, we realized we were in over our heads. Carrots are prone to such inbreeding depression and, since they cross so readily with Queen Anne’s Lace and are difficult to produce well in isolation cages, they’re challenging to grow to seed here in the Northeast. We immediately turned to our dear friend and mentor Irwin Goldman, a public plant breeder at University of Wisconsin, Madison who specializes in carrots.

Irwin jumped in right away.

Instrumental in founding the Open Source Seed Initiative (OSSI), Irwin shared his insight that since Bolero’s parent lines were likely so inbred that it would be counter-productive to simply ‘de-hybridize’ Bolero. ‘Crossing Bolero with OSSI’s Nantes-style carrot population was an elegant solution,’ shared Irwin, ‘combining the specificity of Bolero with the broader but still desirable genetics of a healthy Nantes population makes a much more resilient carrot.’

That winter, Irwin crossed several Bolero carrots into the OSSI Nantes population and sent Fruition the seed the following season, beginning a cycle we would follow for four years to come. The seed was sown at Remembrance Farm, with agronomic selections made at harvest. We selected each root for classic Nantes shape as well as early, abundant leaf production, providing early vigor and early maturity as well as machine harvest. Once we stored the roots 3 months (the optimum minimum vernalization period for carrot), we made taste/texture selections and sent them to Irwin, who planted them in his glasshouses to produce seed over the winter. Irwin’s immense generosity and expertise allowed this biennial crop to be produced annually. This growth-selection-production cycle continued for five carrot generations over the next six years, each season refining our process.

Making the Selections

There was much to select for, Friends! Within the context of Nathaniel’s biodynamic farm, we selected this new variety specifically for flavor, storage, and early vigorous leaf production.

The flavor selections we made were immensely illuminating. I had read that carrots quickly revert back to their bitter ancestry and tasting this ancestry in all her pine-y, resinous intensity was SO eye-opening. Not often, but at first perhaps every one in eighty or so carrots would have a distinct and unmistakable pinesol-esque quality. With selection, the proportion decreased. Still, with every generation, we are making flavor selections. And it’s paid off: Already, Dulcinea is much more sweet and tender than Bolero.

As we made flavor selections, we had three bins: One labeled heaven, another hell and the third one was purgatory. As much as I love flavor wheels and nuance, we were tasting hundreds of roots and had to keep it simple! Delicious ones went to heaven and bitter ones went to hell. Purgatory was of course in the middle and most of them became soup.

We only circled back to ‘purgatory’ if we needed more roots to ensure we had a healthy population size (200 roots), to avoid any risk of inbreeding depression.

By our third generation, we already had a more consistently sweet root than Bolero, perhaps not surprisingly since most commercial varieties prioritize every other ‘market’ quality above flavor itself.

Selecting for long-term storage was also straightforward: Nantes as a market class are long-keeping and maintain excellent flavor. Now that we’re saving 1000+ roots for seed each generation, we’re growing them in the field rather than Irwin’s glasshouses. Though it’s turned our annual cycle into a true biennial cycle once more, this only increases the significance of our storage and flavor selections.

The greatest challenge for us has been selecting for that early, vigorous leaf production that is so much the hallmark of Bolero. At first, we attempted selections by flagging vigorous individuals in the field six weeks after planting. The time invested did not prove fruitful, so we next made vigor selections by simply making a visual evaluation at harvest. Our observations suggest that early, vigorous leaf production may be indicated by above-average leaves present at harvest. Each generation has been improving, though this is by far the trait we’ve seen the least of in the population, making it slower to make more consistent.

In 2018, Remembrance Farm grew 2 acres of this new carrot and will sow 5 acres in 2019, a testament to the quality and reliability of this new variety. With increased population sizes in the field, we’re able to grow increased populations sizes for seed. If seed production continues to thrive, Remembrance will grow this new carrot exclusively in 2020.

What’s in a Name?

Fruition Seeds released this new carrot in 2019, naming her Dulcinea for her sweetness as well as honoring her roots in the Spanish word ‘Bolero’ by naming her for the muse of Don Quixote. She is OSSI pledged, ensuring Dulcinea (and any other carrots developed with her genetics) will never be patented, remaining in the public domain as a commons all we benefit from.

Dulcinea now grows in gardens, on farms and is being evaluated in trials all across the continent. We’re excited to share Dulcinea with the world and are equally ecstatic to continue intensive selections with each generation. Countless ancestors, both human and plant, have made this work possible; it is our privilege and pleasure to continue such traditions and make new ones along the way.

Where Can I Find Dulcinea & What’s Next?

You’ll find Dulcinea at www.fruitionseeds.com and for larger quantities, send me an email: petra@fruitionseeds.com. We select and save the seed of over 400 other vegetables, flowers and herbs, adapting them in our short seasons here in the Finger Lakes of New York. We’ve also developed a short season watermelon called August Ambrosia as well as two tomatoes that are resistant to Early Blight, Late Blight and Septoria Leaf Spot called Brandywise and Summer Sweetheart. For their full stories, hop on over to our website. We’re developing some exciting new vegetables and flowers for you, Friends! And we love to collaborate, so don’t be shy!

In a world increasingly impoverished by industrial and private interest, Dulcinea is the harbinger of a new paradigm. Collaboration between a farmer, a seed company and a public university has created an open-source, organic alternative to one of the world’s preeminent conventional hybrids.

Indeed, Dulcinea may simply look like a carrot. A consistent, sweet Nantes-style carrot. Don’t be fooled. If you sow seeds, you know seeds are not as small as they seem.

Petra Page-Mann, Finger Lakes native, is the co-founder of Fruition Seeds. She loves to share stories, share meals and hopes to see you on the farm one day! In the meantime, write to her at petra@fruitionseeds.com and don’t be shy!
Breeding by Mass Selection on the Southcoast

by Jack Kittredge

The area of Massachusetts and Rhode Island forming the northwest boundary of Buzzards Bay, from Little Compton RI to Wareham, MA, has come to be known as the South Coast, or the more stylized “Southcoast”. The name is recent, according to Wikipedia: “… dating to the 1990s, and sometimes confused with the South Shore -- a region southeast of Boston that includes Norfolk, Northern Bristol and eastern Plymouth counties. [It was] born as a public relations effort to counteract the perceived stigma of [neighboring] depressed mill towns with run-down buildings and high unemployment. Local boosters…began using the term in the mid-1990s in an effort to attract business to an area with ‘the Cape’s climate, better infrastructure’ and ‘relatively low land prices,’ according to Standard-Times publisher William Kennedy.”

For many farmers, however, whatever you call it, the area has been home for a long time. Westport, site of Horseneck Beach, a deservedly famous clean ocean beach stretching more than 2 miles along a protected reservation, an abundance of new wineries, and miles of sandy farmland, has been farmed continuously since the early 1600s when settlers bought land from the Wampanoags. Although driven out and having their homes burned during King Philip’s War in 1674 - 1676, they quickly returned to buy more coastal ‘meadow land’. Descendants of some of those early families are still farming here, as well as a spate of new, younger farmers, many with organic convictions.

One of the newer farmers is Bill Braun who, along with his wife and young son, has made an arrangement with the owners of a Westport farm that has been in continuous production since 1740. In return for access and capital for long term improvements, he farms, improving the infrastructure and building up the soil.

Bill grew up in the South Coast and was a lifelong gardener, mostly raising ornamentals along with a few tomatoes and pumpkins. As he got older he became increasingly interested in growing food.

“I studied philosophy in college,” he relates, “and I was in a masters program at Boston College. I was also playing in several bands and working several temp jobs to support my music habit. It was wearing on me – I’d play for an audience of maybe seven at night, and then go to class in the morning and try to be wide awake.”

In 2008, through a musical connection, he ended up recording some music at Eva’s Garden, an organic farm in the next door town of South Dartmouth. Eva Sommaripa, the owner, specializes in greens and herbs for the Boston culinary market. Bill volunteered for a day and took over her cottage to record music.

“I realized I needed to figure out a way to grow food and keep dirt under my fingernails,” he recalls. “Until you do that you don’t have an appreciation for how growing is hinged to so many other things – environmental issues, social justice issues, globalization issues. It is all in the growing of food – the interaction with the natural world, with plants, and the stewardship of that.”

“All the problems I was trying to address in academia,” he continues, “I was addressing by putting my hands in the soil. I bought organic when I was living in the city, I was under the impression that organic would be expensive. But the nature of an organic system was off my radar, as was an appreciation for the work involved.”

So Braun walked away from grad school and decided to forget about his insurmountable student loan debt for a moment and figure it all out. The joke in the philosophy department when he was there, he relates, was that the two career objectives of graduates are philosopher or bureaucrat. He decided neither was right for him.

The farm he is on is called “Ivory Silo Farm”. That is a perfect name, he says, because an academic couple bought the farm in the 1950s and since they spent most of their lives in an ivory tower the name was natural. The parents passed away eventually and 4 siblings inherited the farm, deciding they wanted to keep it preserved. In 2013 Bill came onboard. One of the kids, now in his 70s, was still there baling hay and keeping the place together.

“When I arrived,” Braun recalls, “I figured to use my Boston and Cambridge restaurant connections as financial catalysts for seed work. They would buy whatever I produced, so I could experiment and try to grow some new varieties. Since then, one has really taken the plunge – 85% of their produce comes just from us. They even come and participate in the farm – harvesting, cleaning, culling.”

The farm is 37 acres, 16 of which are arable. Bill and his wife grow on about 10 of them, sowing 5 each year and fallowing the remainder. His goal is to share the farm with the family that owns it.

“We won’t own it,” he admits, “but we will run the farm. We are making many shorter term investments here, while the owning family makes the really long term ones. We have been given great advantages by the family so that we didn’t have to go so deeply into debt. Other young farmers are also coming down here and figuring out their own ways to partner with landowners. The price tag on coastal New England land makes any other approach prohibitive.”

The couple has about three-quarters of an acre in perennials, many of which they won’t see come to fruition for four to eight years more – mostly fruits, culinary herbs and flowers. They try to find items that work well in organic systems that chef customers might be a good market for – hardy kiwis, pawpaws, Nanking cherries, gooseberries.

They deal exclusively with restaurants as markets, plus doing a spring plant sale with their own varieties. There are so many farmers in the area now that Bill thinks if he started a CSA they would be competing immediately with four other farms. There are three other farm stands within a few miles of them, too, to say nothing of farmers markets. The restaurateurs, however, consistently say: ‘You grow it and we will buy it’. I asked Bill how he got excited about breeding improved crops.

“We grew a lot of salad greens,” he explains, “and a lot of mustard varieties. We had one greenhouse where there were things that got kind of overgrown and went to seed. That greenhouse breeding produced a lot of naturalized plants with several different leaf types, all equally vigorous and cold hardy, and with a great flavor profile. We thought: ‘This is worth keeping.’ So we have been carrying them.
There is considerable variation in the spectrum of leaves in “Eva” mustard, a farm-original genepool.

They are adapting to this location and our conditions. That to me is what this is all about!

“When Frank Morton in Oregon recast his lettuce breeding program,” Braun continues, “he set up what he called ‘Hell’s Half Acre’. It was a half acre where he only grew lettuces, year after year, and let them go to hell. What survived became the foundation for his lettuce breeding program. Something that is abused and abandoned will sometimes, if it survives, have incredible vigor and resilience.

“We are growing mustard this year,” he concludes, “specifically for a seed crop. One thing that is great about our system is that we are not just growing a seed crop of beautiful plants, but we are first harvesting from that crop, sometimes harvesting the hell out of it. Then we are letting it have a break enough to photosynthesize and go to seed. So what gets selected has been subjected to our harvesting system and has adapted to it a bit. You can’t do that with a head of lettuce, obviously, but many crops can withstand a harvesting regimen like this.”

Despite their enthusiasm for this work, Bill and his wife realized a couple of years ago that the way they were piggybacking the seed work onto the market garden was doing the seed work a disservice. They were just struggling to keep up. Braun realized that his initial resistance to starting a non-profit – because I didn’t want to be behind a desk all the time – was inappropriate. It didn’t have to be that way. He could structure it in a way that it could support the work by getting grants and tax-deductible donations from people in the affluent local community here. So they incorporated in October of 2017 and got 501 (c) 3 status for the “Freed Seed Federation”.

Their goals are climate resilience, and to produce regenerative plants suitable for the future. Another goal is to work with farmers in the area interested in developing better plants who don’t have the tools or technical support necessary to undertake it alone. When you get into this on your own, Braun says, you often have questions but no one of whom to ask them. Questions like: “This is looking weird, is it okay?” “Do I have enough now?” “I think I skipped a step. Is that important enough to start over?” It helps to have a local person you can call and from whom you can get advice.

There are about a dozen farms that seem seriously interested in doing the work, Bill says, and continuing with it. Of those, seven actually did plant development work last year and he considers peers. He is the group’s executive director, Honer Breen at Fedco and Hannah Traggis at the Massachusetts Horticultural Society are their two in-house volunteer consultants.

Braun is quick to caution that seed work takes place at a glacial pace and it can be upwards of a decade for anything to really come to fruition. But if a farmer is interested in pursuing this work, he suggests two ways in which it can proceed.

“If a farmer educates herself really well about growing seed,” he explains, “and comes to a seed company like Fedco and says: ‘Give me some seed you need grown out and I will do it,’ that would be one way for farmers to work with seed companies and diversity their operations with seed trials. The other way is if a farmer develops a seed variety they feel good about and ships it around to see if a company wants to distribute it. Some companies like Dan Barber’s ‘Row 7 Seeds’ or ‘Fruition Seed’ have been doing that. Their whole mission is to release cultivars that are flavorful. Farmers can often get a royalty or other compensation for their work with the right companies.

But the financial rewards are not big for working with developing and breeding plants on your farm. The benefits of keeping your eyes on a plant variety for years and years are also adapting it to your soil, or to the weather in your locale, or adapting it to your harvest style and all sorts of other traits that are beneficial to your farm – adding beneficial habitat and pollinator habitat. It is a way of keeping a healthy farm organism.

The other big initiative Bill is involved in is finding things that do well on the South Coast and making sure they stay growing there.

“Turnips and corn are the main varieties we work with for preservation,” he reveals. “Then there are the varieties we work regularly in our market garden. We pick just one pepper or one watermelon or one muskmelon and use mass selection to keep picking the best. We are not making our own crosses intentionally yet.”

Braun feels strongly about the importance of growers selecting, saving, and breeding crops which are better adapted to their locations and methods than what is available commercially. That right has been under some legal constraints since the 1980 Supreme Court decision in Diamond v. Chakrabarty. The court held that any live, human-made micro-organism is patentable, a decision that opened the floodgates for patenting seeds.

The burgeoning seed movement that we are now seeing is a response to that effort to privatize seed, he asserts, based on the belief that, like air and water, seed is a public common that has been selected, developed and improved by millions of hands over the entire trajectory of civilization.

He points to some encouraging models for seed control that are emerging. One is the “Open Source Seed Initiative”, which is just a moral code right now. But the idea is that by using seed acquired with this label you are free to save, plant, improve and sell it, so long as you do not restrict any progeny of this seed and it is open to the same public use. The label is printed on bags and is on the websites of companies that pledge to be Open Source, like Fedco.

Another model is farmer-based small seed operations. Many seed companies were, and more still are, farmer-based initiatives evolving from a passion for seeds. Bill deals with a number of these.

“We had a friend with a 2 acre CSA in Rhode Island who,” he says “over maybe ten years, created original varieties of tomato, watermelon and kale. They thought about starting a seed company to pass them along to others, but they realized soon that the packaging, marketing, distribution, etc. were all way more than they could handle even on top of the farm. So they let the seed company go after 2 or 3 years and passed some of the varieties on to us to evaluate and pass along to other seed companies. We also get a lot of seeds from Uprising Seeds, run by a couple in Bellingham, Washington. It is sort of like a candy store for us. They curate the overwhelming variety of what they grow and maintain it from year to year, selecting it for quality – and work with other small seed growers in the region.

“Some farmers find a niche, though,” he continues. “Frank Morton in Oregon is a hero of the small seed growers. He learned early on that you need to breed in situ for small organic growers. Most commercial seed has been bred for conventional systems and you need to adapt it for organic ones. He saw how important that was and decided to pay attention to it. There is a whole community in the Northwest who are doing this kind of breeding work,” he concludes. “Frank, John Navazio, who helped found the ‘Organic Seed Alliance’, many others come from there. It seems to be an area naturally geared to growing seed. The Northeast lags behind. There are some growers in New England – doing the whole thing from seed, selecting it for quality – and work with other small seed growers in the region.

To illustrate his point Braun cites the fact that California grows something like 60% of US spinach, and there are only about 5 really large growers there. So they very much dominate the spinach seed industry that is based on groups in a variety that is “tolerant” and not “resistant”, then that is a problem. Growers at that scale are essentially raising a monoculture and court the resistance breaks down completely.

Another strategy is called “horizontal” and involves many more genes. An example would be breeding something for taste by tasting it and selecting what is best. This is more subtle and takes longer than vertical trait breeding.

He says that plant breeding for traits like resistance to a certain pathogen or parasite often focus on a single gene in the plant that disables another gene in the pathogen or parasite. This is called a “vertical” resistance strategy. The idea is that as long as the pathogen or parasite does not itself evolve around that genetic block. Once that happens, the resistance breaks down completely.

Another confusing set of terms, Bill suggests, is whether a group of plants is a variety, a landrace, or a gene pool. A landrace is the most diverse group, but is generally adapted to one locale. It must be maintained there for a long period of time. A landrace can produce quite different looking plants, tall, short, fat, thin, different colors, but is grown in a specific region from its own seed. An indigenous variety, for instance, is a wild relative that sets seed. The same variety of plant, if grown out in different areas, can eventually produce various landraces.

A variety of beets, however, looks a certain way, which it would be nice to have plants adapted.”

Your model is called “man-made small seed companies. Some companies apply for patents. This can be a cumbersome and takes longer than vertical trait breeding.

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A variety of beets, however, looks a certain way, which it would be nice to have plants adapted.”
grow two varieties side by side and have Bumblebees around they will cross.

Hybrid versus open-pollinated plants are another common set of terms in plant breeding. Open-pollinated plants are those that will maintain relative stability of traits through generations of breeding from their open seed. Hybrids are plants produced from seed set when two distinct parents cross. If the parents are each bred close to uniformity themselves, when they cross they will produce a predictable off-spring. Often these offspring hybrids will have what is called “hybrid vigor” or exceptional qualities. The offspring of hybrids, however, do not breed true and usually the special qualities are lost.

“The hybrid is an interesting case of ownership in seed,” Bill observes. “If you have developed one, only you know the exact parentage of that hybrid. To control that parentage you have to breed both parent lines to near uniformity and sustain them there. But that way people have to come back to you for hybrid seed since only you can breed it from exactly the same parents. As a breeder you have a much more secure revenue from a hybrid than from developing an open-pollinated breed, and that control became a perverse incentive for breeders to develop large numbers of hybrids.

“A lot of people think hybridization is good,” he continues. “But how stable is that over a number of years compared to an open pollinated variety that is well maintained? If you plant seed from hybrids you will get a lot of expressions of recessive traits. Open-pollinated varieties are a population that is much more stable. They will grow true to type from generation to generation there will be drift if you are not selecting every year for the same qualities.”

“Hybrids do have a place. A lot of the hybrid material that is out there growers rely on. But hybrids are overwhelmingly bred for commercial agriculture. With our small organic farms, do we want acres and acres of carrots that can all be harvested at the same time? Or do we want plants that are more appropriate to our sizes and markets?”

One of the plants that Braun has been focusing a lot of his preservation work on has been a local luminary for almost one hundred and fifty years. It is an unlikely creation itself, and continuing it’s viability and value has been a story not without some local color and drama.

As Bill tells the story: “We in Westport have been fortunate enough to inherit a cultural treasure, which is the Macomber turnip. Circa 1876 the Brothers Macomber had this new variety that they brought back from the Philadelphia Exposition, or perhaps was an accidental cross in their field of a rutabaga and a true turnip. That is a crossing with a likelihood of only one in every few thousand, but the offspring of that hybrid had the qualities of both plants. It grew like a weed and is incredibly well adapted to our conditions. It has a unique flavor profile – the sweet bite of a turnip with the girth and storability of a rutabaga. But it does not have the sulfuric flatulence usually associated with rutabagas. It is widely consumed for Thanksgiving dinner in Southeast Massachusetts and is considered a treasure of a vegetable here and in some circles of chefs in Boston and New York.”

“I like it,” he concludes, “because it intersects flavor and food security. You can store it in your fridge or root cellar until June, yet it has myriad applications raw or cooked. You can slice and ferment it like sauerkraut, it is heavenly mixed with potatoes and mashed. It sells well to restaurants into the spring.”

Recently, however, young farmers began coming down to the South Coast, starting farms and wanting to grow the Macomber turnip. But some of the old guard were not cooperating. It was a major crop for some of them, as important as winter squash, and they weren’t happy with the extra competition. More than one story has been told of confrontations in fields at night – farmers with shotguns protecting their turnips. Some when sold at market are cut so deep that there is no chance of them sprouting the next year if replanted.

(Here we must pause and explain that the Macomber turnip, like its parents, is a biennial. This means that it requires one season of vegetal growth to build up the strength for seed production. Then, the next April the harvested root, instead of being sold to eat is replanted for seed, which is usually ready for harvesting in Westport in July. This replanting would not be productive if the bulbous root has been cut so deeply by the farmer that it will not sprout that second season. Interestingly, often biennials produce a lot more seed than annuals because that extra period of vegetative growth strengthens them. They also require vernalization, a period of 8 to 10 weeks during which they have to be maintained below a certain temperature in order to produce flowers.

That cold triggers some mechanism to tell them to stop producing turnip and start making seed. Also interestingly, the seed on these turnips is dehiscent, meaning it will shatter and explode away from the plant upon harvest, enabling the seeds to spread. Birds, who love the seeds, are also a carrier.)

To return to the story, there is also a Cape Cod turnip and a Gilfeather turnip, each with similar attributes to the Macomber one. No one knows exactly where or when the strain emerged. Some people have tried to legally protect it, but so far unsuccessfully.

“Fast forward to the present day,” Broun explains, “and the few people maintaining the turnip were not selecting the best of the best anymore. The best were going to market and the ones leftover in the field became the seed crop for next year. We acquired seed and when we grew it we got lopsided turnips, turnips shaped like footballs, ones with long necks, or blackheart. We decided to work on it to restore it. So 8 years into my first growing it, just by selection, we have a variety which has received very favorable feedback.

“This is how farmers have traditionally improved crops,” he continues, “mass selection. You walk the field, you survey the crop in all its variety, you flag the best looking ones, plant them the next year and take your seed from those. The more you are selecting the same thing over time the more you are going to get that same thing.”
Brassicas have a perfect flower, meaning one with all the flower parts, male and female. But they are self-existential, meaning that one brassica’s flower cannot reliability pollinate itself. So you will have a mix of paternal and maternal genes in that flagged turnip’s seed that will differ somewhat from the maternal genes that created that particular turnip. But if you select consistently over the years the population will become closer and closer to what you are selecting for.

“By now, frankly, the old timers who were very protective of the crop have either gotten out of the game or died,” Bill admits. “We now save about a hundred turnips a year for seed. Then when we give seed to our farmers, we reserve the right to take 30 turnips from their crop the next year. So we are selecting on their farms as well. We put them all in storage and plant them the next year, let them go to seed, clean the seed, and redistribute it to farmers again. We are hoping we can continue to do this work without a monetary exchange. But the abundance of Nature is amazing! Eventually if we have a plethora of seed we may sell seed packets.”

Another of Broun’s preservation projects is what is known locally as Narragansett White Corn or Rhode Island White Corn or New England White Cap Flint Corn or Johnnycake Corn. The story goes that the Narragansett tribe shared this variety with the settlers and it became widely consumed until corn came into fashion in the mid 1800s. Bill got the seed from a man named Harry who was in his mid eighties, one of three or four of the last growers growing it. There was a local market for it, so moderately generous, but a brassica is! And the seed is not so difficult to process as tomatoes.

“They do have dehiscent pods,” he admits, “so they shatter to release seed when they are dry. If you were to let everything get to 100% dry the bottom seeds would already be shattering. So we usually harvest between 2/3 and 3/4 maturity to avoid that. We harvest them and hang them in bags until dry, then we thresh by throwing them on a tarp and having a dance party! You can also get a box covered with a screen of the right size. You shake the pods over the box and the seed falls through the screen holes while the chaff gets caught. Or if you feel lucky you can let a breeze blow the chaff away while you catch the heavier seed.”

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Breeding for Regional Organic FARMS

by Adrienne Shelton

I spent the last day of my graduate school career as most students do – my stomach locked into a tight ball of jittery nerves and my mind struggling to suppress the irrational fear that my research, which had consumed my life for five years, contained some critical flaw that I had overlooked. My thesis was unconventional. I had helped to breed an open-pollinated variety of sweet corn, developed by and for organic growers, using a method called participatory plant breeding. I had explored the history of organic farming in the United States, as well as the complicated evolution of intellectual property rights in relation to seeds. Drawing on both biological and social sciences, I argued that organic growers require unique variety traits adapted to organic production systems, and that involving growers in the breeding process is an effective way to accomplish this goal.

Looking back on that day, as I defended my PhD dissertation before a five-member committee who would ultimately determine whether I passed or failed, I can no longer remember most of the questions that they asked, nor how I responded. Yet one comment made by committee member Dr. Mike Casler has always stuck with me. Dr. Casler is a forage breeder at the University of Wisconsin-Madison, and an exceptional statistician. Statistics was a challenge for me in graduate school, and I had been particularly worried that Dr. Casler was going to find an error in my statistical model that I would be unable to explain or justify. To my surprise, he seemed quite satisfied with my work and told me (paraphrasing): “In the end, breeding is a pretty simple equation. A farmer’s job is never easy. Whether it is increased production costs, erratic weather, new pests or disease challenges, there are always multiple factors chipping away at the farmer’s bottom line. As a breeder, if I can develop a variety that gives a little of that bottom line back to the farmer, through increased yields, better disease resistance, or improved nutrition, then I have done my job and I can sleep well at night.”

Ultimately, the committee did grant me my degree, and the feeling of relief and accomplishment is just about the only other thing I remember from that day. Since graduate school, I have worked as a post-doctoral researcher, a product development manager for High Mowing Organic Seeds, and now as a breeding manager for Vitalis Organic Seeds. I am often asked if I would rather be working as an organic product specialist for Vitalis Organic Seeds. I am always asked if I would rather be working as a breeder, given my Masters and PhD training. In those moments, I always think of Dr. Casler and the wisdom he shared with me. As an organic product specialist, my role is to trial experimental varieties, developed by dozens of breeders, on organic farms in the Northeast and Midwest. Through these trials, I am able to influence breeding objectives to ensure that the varieties being developed meet the regional needs of organic growers, and are appropriate for agronomic and market trends. Rather than just focusing on one or a few crops (as I would likely have to do as a breeder), I have the opportunity to identify new varieties that are best suited for organic production in a wide diversity of crops, and which can help improve a farmer’s bottom line, however he or she chooses to define it. Dr. Casler’s philosophy is the foundation of the work that I do, and indeed, I do sleep very well at night!

Vitalis Organic Seeds, a division of Enza Zaden, was founded in 1994 in the Netherlands, and is a global leader in organic breeding and seed production. We are an independent, family-owned company that focuses exclusively on breeding and seed production. We produce nearly 500 certified organic seeds, free from pathogens and weed seeds, and with excellent germination. We strive to meet these standards with every bag of seed that we deliver. The variety traits required by different types of growers, however, is more variable. The critical traits that will make the difference between whether or not a lettuce variety will improve the bottom line of an organic lettuce grower in California is likely very different from the critical traits needed by an organic lettuce grower in Massachusetts. Factors such as climate, disease pressures, production methods, post-harvest shelf-life requirements, and consumer preferences all influence the focus of the breeding program. Plant breeding does not work well in a one-size-fits-all model. Instead, plant breeding needs to be approached on a more regional scale, working in collaboration with the farmers, to fully understand the traits that are required to develop a successful variety.

As a breeding company, we work with farmers of all scales, from large wholesale producers to small direct market gardeners, and everything in between. All of these growers expect and deserve the highest quality organic seed, free from pathogens and weed seeds, and with excellent germination. We strive to develop a variety that gives a little of that bottom line back to the farmer, through increased yields, better disease resistance, or improved nutrition. All of these growers expect and deserve the highest quality organic seed, free from pathogens and weed seeds, and with excellent germination. They strive to meet these standards with every bag of seed that we deliver. The variety traits required by different types of growers, however, is more variable. The critical traits that will make the difference between whether or not a lettuce variety will improve the bottom line of an organic lettuce grower in California is likely very different from the critical traits needed by an organic lettuce grower in Massachusetts. Factors such as climate, disease pressures, production methods, post-harvest shelf-life requirements, and consumer preferences all influence the focus of the breeding program. Plant breeding does not work well in a one-size-fits-all model. Instead, plant breeding needs to be approached on a more regional scale, working in collaboration with the farmers, to fully understand the traits that are required to develop a successful variety.

My work with the Northeast and Midwest, I am particularly engaged with our breeding programs that are developing varieties best suited for the majority of organic farms in these regions – small- to medium-size diversified vegetable operations with a mix of direct and wholesale customers. For example, we are currently working on a project to develop an improved Buffalo tomato. The original Buffalo was a 200 gram, deep globe beefsteak with medium-early maturity developed by Enza Zaden in the 1980s. Buffalo eventually made its way to the United States, and was soon grown widely in high tunnels in the Northeast. The variety was especially appreciated for its outstanding flavor and thin skin. Its Achilles heal, however, was that the variety had very few disease resistances. As Enza Zaden began to release newer tomato varieties with improved resistances, Buffalo’s popularity declined and the variety was dropped from the portfolio. For Buffalo aficionados, however, this news was most unwelcome. There are still rumors of certain growers in Vermont who have a stockpile of the original Buffalo seed stored in their freezers. Another grower told me that he owes the success of the original Buffalo seed stored in their freezers. Another grower told me that he owes the success of the original Buffalo seed stored in their freezers.
of his farm to the Buffalo tomato. He believes that he would not have the loyal customer base that he does now, if it were not for his introduction of the Buffalo tomato to his customers early in his farming career. "This variety and its quality of that tomatoes got his customers hooked, and they have stuck with him ever since."

One organic grower in Rhode Island, Max Hence, was especially determined to bring the Buffalo tomato back to the Northeast. About five years ago, he started making inquiries, and before long he was connecting with the Emerald Isle breeding team in Spain. Based on Max’s description of the variety of the tomato high tunnel tomato growers in New England, the breeders agreed to work on an improved Buffalo. It took a few years of crossbreeding to develop an improved line that had higher yield, better taste, and more disease resistance. The Emerald Isle breeding team in Spain was especially determined to bring the Buffalo tomato to New England, and they were successful in achieving this goal. The variety has been well received by customers in the Northeast, and it has become increasingly popular in recent years. It is a great example of how organic farming can lead to the development of new, high-yielding, and disease-resistant varieties of crops that are well adapted to the local climate and market conditions.

A final example of a breeding program that I am working with is red kuri winter squash. Red kuri is a minor winter squash in the United States, but it is very popular in countries such as France, Germany, and Japan. In addition, red kuri is unique because it has significantly more organic production compared to conventional production in Europe. Red kuri squash has a rich, nutty flavor and deep red color, which is a high source of beta carotene, an antioxidant and precursor to Vitamin A. Unlike other hard squash, the skin of red kuri can be cooked at an incorporated into soups or stews, making this squash easier to prepare than many other types.

Our red kuri breeding program is located at the original Vitalis research station in Voorst, NL. The trials are being conducted on organic farms in RI, VT, NH, and CT, with input from the growers serving as the critical determining factor in choosing which line will become the next Buffalo tomato.

Developing an improved Buffalo is an example of a breeding project initiated by an organic farmer, with a focus on exceptional eating quality and specific disease resistances required by tunnel growers in New England. Middle aged men will still be walking gingerly and choosing carefully, infusing with gross texture and metallic flavor, with the trade in a few years. I could even develop a new variety that is unique to the Northeast, such as a red kuri winter squash. The red kuri variety that I am developing is unique because it is resistant to Verticillium wilt, a disease that has been a major problem for organic growers in the United States. In addition, red kuri is unique because it has significantly more organic production compared to conventional production in Europe. Red kuri squash has a rich, nutty flavor and deep red color, which is a high source of beta carotene, an antioxidant and precursor to Vitamin A. Unlike other hard squash, the skin of red kuri can be cooked at an incorporated into soups or stews, making this squash easier to prepare than many other types.

The Natural Farmer
by Heron Breen

When we think of vegetables & fruits in their raw form, we would rightly associate them with the cure, the “superfood”. You might say, “Nutrition is one of the inherent core motivations behind organic gardening & farming!”

Superb: You are a reader of The Natural Farmer, I am writing an article for The Natural Farmer, we should understand each other. Nutrition is our unspoken word when we grow, eat, and promote local food.

So, first off, blunt question: if a vegetable does not taste good, could we say it is nutritious? I can breed something that, in theory, has all sorts of healthy “things”...but if it is bland or “meh”, you can trust that variety will be out of the seed trade in a few years. I could even develop a new “super food” variety that will cure hemorrhoids and fascism. But, if that veggie or fruit is naturally infused with gross texture and metallic flavor, made to order to be gross and ugly, the all-right will still be vowing various designs for walls. And yes I am lumping texture and flavor into the concept of “taste”.

So, for something to be nutritious in the real world sense, it must taste good. If we are unwilling to compromise on the “taste” part of “nutrition”, then nutritional qualities are irrelevant. Yes, I know “good” is from the tongue of a beholder, and also that “taste” is hogwash in our sugar-addicted society. But that is the average person’s comprehension of how to consume food. We can see that the average person’s comprehension of “superfood” is a major resurgence! Well put! And I am one among many devotees and champions of forgotten “awesomeness” and have spent many years speaking and pontificating on how-to save such things. Many heirlooms were discarded due to the market and social pressures of their eras, and it is totally acceptable that we re-discover them.

Truth be told, though, some older varieties taste awful, and were justifiably abandoned for greater or super as it is sometimes less-boring. But this is a process of “taste” adaptation that is occurring at Vitalis Organic Seeds. We serve a very diverse group of organic growers, in the United States and around the globe, that meet the needs of our customers, and to ultimately help organic growers be more successful, we are committed to a multi-local approach that values the input and feedback of our customers. We strive to get ever closer to achieving our mission of creating an organic world together.

Adrienne Shelton is an organic product specialist for Vitalis Organic Seeds. She lives in Vermont and has been working in organic agriculture for 20 years. She can be reached at a.shelton@enzazaden.com. More information about Vitalis Organic Seeds is available at http://usa.vitalisorganic.com.
Conversely, our collective consciousness can also be quite stubborn! As gardeners and farmers, cooks and eaters, we can be aggressively prejudicial toward the varieties of vegetables and fruits we grow or enjoy. I have been given a sharp demonic eye when tempting a favorite “Amish” acolyte with a different saucy option. Within the commercial seed trade, 100s of new varieties will try for decades to steal a little of the stage from a classic, to no avail. The Big Beef tomato, Silver Queen & Kandy Korn sweet corms, Fordhook Swiss chard, Marketmore 76 cucumber...these are survivors whose shares of our collective consciousness have not been touched by literally millions of dollars in newer plant breeding R&D.

So, even if a variety is nutritious, tastes great, and performs well in today's agriculture, it has to be that darn lucky variety to breach the garden & farm seed trade groupthink. The lifespan of a very successful variety in the marketplace might reach 20 years. More commonly the introduction spatters, and the variety will last maybe 5 years. In plant breeding, we throw away untold hundreds of lesser seeds to discover the best genetic combinations -- even with our best often ending up on what Luther Burbank called his yearly "$10,000 bonfires" (early 1900s money, you do the math).

Breeding and introducing new varieties mostly just adds to the massive pile of forgotten plant breeding due to the challenges of social and commercial recognition. For some to be nutritious in a real world sense, it must taste good AND perform in the agricultural system of culture / time AND that special something must be able to capture our attention in the seed marketplace. To consume a tasty nutritious variety regularly, we must be able to grow it with competence, and its gotta self.

Up to this point, you may feel I have been flippantly painting a fairly daunting picture of the "meta" hurdles plant breeding and crop improvement must overcome. Two saving graces keep this cycle of exploration called plant breeding in action. First, common to all plant breeders, belief, all plant breeders are incredibly adventurous, brave and bold (and smart & attractive & generally fun to hang out with at parties). Second, plants are incredibly forgiving and beneficent, and we often even help in spades to our clumsy meddling rather than because of our skilled genius.

When a plant breeding project begins, some or all of the aforementioned real world pressures are prudently considered. The duality is that a certain amount of difficult work must be indulged in before any outcome can really be assessed. This is especially true when one is breeding for improved nutritional traits.

Putting aside all the variables I have put in bold, yes of course different varieties of a specific crop DO contain differing levels of nutritional benefit. Sometimes this oscillation is within the crop species itself and is relatively easily worked on by breeders. More often we find the "golden ticket" hidden with another closely related domesticated species, or even a wild "cousin" species. It is possible to "cross" two closely related species, meaning that a few viable seeds result when we transfer pollen between the species. Just as often, success requires thousands of seedlings result when we transfer pollen between the closely related species, meaning that a few viable

Breeding lines were developed by breeding crosses between that very interesting but diverse wild accession and domesticated S. lycopersicum, to more fully capture these good traits into a usable form. As is often the case when using a wild species in breeding, excellent traits often "drag" along less desirable traits. High lycopene in tomato can link itself with soft or mealy/mushy texture, and "off" or unusual flavors can also plague wild-blooded gene pools. These negative relationships would be painstakingly overcome.

Foolad's research reflects the term "pre-breeding". This seemingly dismissive term is actually a shorthand within the plant breeding community for the extremely time-consuming and epically important process of translating a bunch of mixed up genetics into a usable form. Pre-breeding is where research is done to seek out solutions to problems and where new breeding techniques are often developed. If reflected in woodworking, pre-breeding is where someone has selected a very good tree, expertly felled it, and skillfully sawn the logs into boards. Does that mean there are no knots or warps? No, but it means excellent raw material is available for the next stage of "building" new varieties.

Let's take a moment to look at lycopene itself. Occurring in our standard tomato naturally, lycopene is a bright red carotenoid found in many red fruits and vegetables in varying levels, but occurs in select non-red produce as well. Unlike many nutrients, cooking actually increases its availability, as do fats/oils in combination (hence one more value of great olive oil!!) Like many antioxidants, scientific research has not been able to verify the specific benefits that lycopene offers the human body thru diet. Various studies support its role in overall cardiovascular health and lower blood pressure, but other studies can find no essential role in the body nor any direct benefit.

Research into nutrition is often contradictory and results vague, in part because our reductive model of science is not suited to discovering systemic functions. (Also because our country doesn’t value nutrition highly.) That should come as no surprise to readers of The Natural Farmer. Nor should the concept that eating a rich and balanced diet (combined with fresh air, exercise, and not being a stress-case) is good for us. Adding excellent tomatoes to your life can’t be wrong, as centuries of human use in the Americas and Mediterranean can attest.

Dr. Foolad presented his breeding research to the greater community at a tomato symposium in 2009, and was approached by Rob Johnston, JSS founder and now-retired breeder. Foolad sent the Johnny’s breeding program his best development lines for their evaluation and test crossing. JSS already had some very good grape and cherry tomato breeding lines of their own, and hoped to combine their own selections with Foolad’s vigorous and disease resistant material. At this point, the high lycopene content was not the primary motivator for JSS, but seemed promising.

Thru trial and test crossing in 2011, Johnston and crew identified which of the Penn State lines held the most promise as hybrid parents. In 2012, Johnston turned over the project to newly hired tomato breeder Emily Haga to explore the full potential. 100 test crosses between the best Penn State line and JSS cherry and grape inbred parents were tested in 2013. The firm texture of grape "parentage was found to be a successful combination to offset the flesh softness linked to high lycopene content. And of course the lycopene-linked bold color and great flavor were sought within the population.

In 2014, the JSS breeding staff assessed the very best of these 100 crosses in larger plant numbers, hoping to view the plant habit and other traits more closely. At the same time, the JSS and Penn State parent lines of these winning test crosses were evaluated for uniformity, and single plant selections were made as needed to further refine stability. When looking so closely at the chosen Penn State parent lines, a new challenge was observed by the JSS crew.

Wild tomato species often have flower structures that encourage bees to perform pollination activities. Seed savers among us may also know this from the heirloom tomatoes that still express this trait. This
is the infamous “exerted stigma”, exposed pistilate/ staminate flowers occurring unintentionally between tomato plants in more “original” tomato germplasm. The exerted stigma extends beyond the anthers before they shed pollen, allowing an interval where pollinators could wing by for a visit with pollen from another tomato plant.

In commonplace modern tomatoes, the stigma stands among the anthers as they shed pollen and remains below or level with the anther “cone”. Before bees can intercede the flower does the job itself and the entire stigma and pollen from the eastern tomatoes helps breeders stabilize breeding lines without having to intervene with hand pollination work, saving a ton of detailed labor. It also allows breeders to plant many breeding projects & lines together, as there is little risk of crossing and inadvertently scrambling the population.

But, in the case of the select Penn State lines, bumblebees were eagerly working the flowers! An apparent outcome of their wild parentage, the Penn State tomato plants were bee-friendly, with potential out-crossing between plants and mixing up of the genetics of the parent lines. Getting and keeping the Penn State parent lines “fixed” (pure) added unexpected complexity. But Emily and the breeding crew tackled the issue handily.

As a single promising hybrid was determined, much broader trial across the US was required in 2015. Getting feedback from lots of growers and regions is crucial to releasing a potentially successful variety. Dr. Foolad was included in these trials as well, testing the lycopene content of the cross and the comparison commercial “checks”. Foolad and independent labs determined the new hybrid contained 3 times the lycopene of the any of the “check” varieties. The decision was made at this time to promote the lycopene content as part of the new variety description.

Finally, in 2017, a winning hybrid between a JSS grape parent and the Penn State material was fully ready for release. “Valentine” was not only vetted by the AAS judges; Johnny’s also brought chefs and the public into the fray. Chef’s Jason French, Frank Giglio and Tim Wastell were given free rein to put “Valentine” thru its paces in a number of different preparations. The public was treated to these creations by Lane Selman’s Culinary Breeding Network event in Portland, Oregon and at an autumn event in Unity, Maine during the Common Ground Country Fair weekend.

“Valentine” has met all the criteria required of successful crop improvement toward nutrition. Its distinct flavor is excellent; deep and rich with great texture. The disease resistance and vigor makes it easier to grow that many comparable varieties. Yield has been very high and of high quality in all comparable trials. Its stunning crimson color helps it gain individual market recognition. And, due to diligent trialing and vetting, “Valentine” is more than holding it own in seed sales.

The reader may find it odd that I, an employee of a fully different seed company than Johnny’s, would take the time to examine and present their success. In the seed “realm” and plant breeding circles we do each other and our calling disservice if we do not laud hard earned excellence. While we are competitors in many ways, we are also colleagues and contemporaries. Dear reader, you’ve surely suffered thru my article, but please join me in giving “Valentine” three cheers: “Brave work, Well done, In gratitude!!!”

Heron Breen continues a 20-year career at Fedco Seeds of Clinton, Maine. He also works with the seed non-profit Seeds of Renewal; promotes perennial farmer breeding and seed saving in the Northeast. As well, Heron operates a small seed saving and plant breeding farm in central Maine.

Plant Breeding to Save the Future

by Nate Kleinman, co-founder of Experimental Farm Network

For the first 10,000 years of agriculture, every farmer was a plant breeder. Though most would never have described themselves as such, by the simple and intuitive process of saving seeds from their best plants, farmers taught themselves how to breed plants — and they were incredibly good at it.

Practically all of the crops that feed humanity today were gradually domesticated from wild plants and selectively improved year after year by people with the basic human will to survive. Better crops — more productive, more reliable, more resilient — meant a better chance at survival.

Today, with the twin specters of climate change and ecological collapse haunting our species, we face threats to survival unlike any our ancestors ever knew how to work with people and we knew how to mobilize volunteers. We worked with churches and community organizations that already had strong connections in their neighborhoods. We used social media and conference calls to build new connections. We even hijacked Amazon’s online wedding registry system to get donors anywhere in the world to send exactly what was needed, where it was needed, as quickly and efficiently as possible. We worked fast and we worked hard.

I was still in the thick of this work when I took a break to attend a conference in Quebec. One of the speakers was author Eric Toensmeier, and the focus of his talk was “carbon farming and perennial industrial crops.” He discussed the importance of transitioning away from annual monoculture farming — typified by the GMO corn and soy rotation that predominates today’s agriculture — which is a huge source of carbon emissions. His proposed solution was to move toward perennial-centered polyculture farming, with existing perennials like fruit and nut trees interplanted with annual vegetables and grains, which should eventually be replaced by new and improved perennial crops, especially grains, oilseeds, and vegetables.

Toensmeier catalogued a wide range of perennial plants with great potential to become perennial crops: Osage oranges (Machura pomifera) as a possible source of edible starch; Crambe species (like sakelake) as a possible source of industrial oil; Illinois bunt dispenser (Desmanthus ilinoensis) as a possible replacement for soybeans; hybrid chestnuts as a replacement for corn; and many more. Most of our staple crops are annuals not because domestication of perennial plants is impossible, but because breeding annuals is so much less time consuming. Many perennials with the potential to become productive crops take five or ten years (or many more) to reach maturity, so even just three generations of improvement might take thirty years instead of the one or two for annuals. Yet the ecological real, as long as someone is working to fulfill it.

The advantages of perennial wheat were obvious to the early researchers — perenniality means no need to till and replant each year, and longer roots mean less need for water and less soil erosion — but they are not widely known because of an issue: breeders are releasing immense amounts of carbon into the atmosphere and perennial plants take carbon from the atmosphere and put it into the soil, perennial wheat could become a significant weapon in the fight against climate change. If we can develop a whole new agricultural system based on perennials, then we can help shift society away from its current dependence on fossil fuel based agriculture. If we can learn how to develop crop varieties that can work together, that can work without the need for hand pollination, then we can save ourselves from our own destructive practices.

Yet the ecological real, as long as someone is working to fulfill it.

In recent decades, plant scientists have made major strides toward the development of viable perennial wheat (or wheat-like plants). At Washington State University, Dr. Stephen Jones and colleagues have been focused on perennial wheat over the last few decades. They recently introduced a perennial wheat hybrid called ‘Salish Blue,’ which is probably the most promising wheat grass hybrid yet. The Land Institute in Kansas — which was started by Wes Jackson in the 1970s with the goal of preserving topsoil in the Midwest — largely abandoned its efforts at creating perennial wheat varieties in the 1990s but has focused on basic domestication of those perennial relatives. Through intense selection for the largest seeds, they have turned hybrid wheatgrass into a new perennial grain called Kernza (a trademarked name), which is in the early stages of commercial-
"Tim Peters' perennial wheat, a hybrid, survived four winters in New Jersey."

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Identification, even as they continue to improve it. The Land Institute is also working on domesticking perennial sunflower relatives as oilseed crops, and breeding hybrid sorghums as perennial grain crops, among other programs.

As I sat there in Quebec listening to Toensmeier talk about the challenges of developing perennial wheat and of the many missed opportunities over the past century, I had a lightbulb moment: why not apply the same crowdsourcing, grassroots ethos of Occupy Sandy to the problem of revolutionizing agriculture? I figured if a rag-tag group of inexperienced millionaires could mobilize 60,000 volunteers on less than a shoestring budget, anything is possible. Since much of plant breeding is essentially looking for a needle in a haystack, it only makes sense to have as many people looking as possible. In that moment, I realized that I could either spend the rest of my life bressing from disaster — for we know there will more and more disasters — helping to pick up the pieces, or I could refocus my life toward doing something to get at the root of the problem.

The seed was planted that soon grew into the non-profit cooperative Experimental Farm Network (or EFN), which is now in its sixth year.

The mission of EFN is to facilitate collaboration on plant breeding and sustainable agriculture research, with a particular focus on developing new crops for carbon sequestration and climate change mitigation. Along with my co-founder Dusty Hinz and a small team of open source computer programmers, we built an online platform (www.ExperimentalFarmNetwork.org) that allows anyone to post a project, recruit volunteers, and stay in touch with their team. There are currently 21 projects using the site, including a perennial kale project led by Chris Homanics of Oregon, an upland (dryland) rice project led by Sylvie Davatz of Vermont, and — taking us full circle — a Chinese yam (Dioscorea yam-tacha) aerial tuber project from Eric Toensmeier himself.

The EFN site is free to use and open all its new. It’s still not perfect, but it is getting there. At this point, the majority of projects on the site were put there by me. They involve a wide range of mainly perennials for crop development and improvement: sorghum (Sorghum bicolor), jojoba (Simmondsia chinensis), chinquapin chestnut (Castanea pumila), mayapple (Podophyllum peltatum), Tartary buckwheat (Fagopyrum tataricum), monkey puzzle tree (Araucaria araucana), sword beans (Canavalia), prickly pear cactus (Opuntia), beach plums (Prunus maritima), maypop passionfruit (Passiflora incarnata), and Job’s tears or adlay grain (Coix lacryma-jobi var. ma-yuen).

While a few of these crops are annuals (Tartary buckwheat) or are commonly grown as annuals (sorghum, sword beans, and Job’s tears), most of them are long-lived perennials. Of those, only the maypop passionfruit reaches maturity in less than three years. Monkey puzzles (a nut-bearing Chilean conifer) can take three decades to reach bearing age — but after that might produce food for another thousand years. Projects like these must therefore extend well beyond the lifetime of the researcher who initiates them. They may not reach fruition for many generations — which is why building a decen-

ized, open organizing structure was so important to us with EFN.

You may be asking yourself, “Sure, this all sounds interesting. But who pays for it?” Indeed, plant breeding is not cheap. At a minimum it takes land, labor, equipment, and lots of time. It also takes ac-

cess to seeds and other propagative material. Since our earliest discussions, EFN has operated under the assumption that people would be willing to give of themselves for a project as important as this one. We’re thankful that our faith in humanity has thus far proved justified. Dusty and I began looking for land in 2013, intending to use it for our own re-

search projects and rare seed grow-outs, and in early 2014 we sealed a handshake agreement to begin farming a beautiful patch of land on a small family farm in rural southern New Jersey. The owners — Sandy and Chris Dietrich — welcomed us into their lives and have still never charged us rent.

EFN soon achieved 501(c)(3) non-profit status and formed an all-volunteer Board of Directors (featuring some truly impressive plant profession-

als including Kristin Baxter of the Garden Justice Legal Initiative, Sally McCabe of the Pennsylvania Horticultural Society, and legendary seed-saver Wil-

tiam Woys Weaver of the Roughwood Seed Collec-

tion). We determined early on that we did not want to become dependent on wealthy donors or founda-

tions — though we certainly welcome their support — and so we decided to create a small-scale seed company inside EFN to fund our non-profit work.

Since Dusty and I were prepared to put everything we had into EFN, and Sandy and Chris were gener-

ously offering us use of their farm, we had land and labor covered. Chris turned over a piece of their field for us, and our friend David Siller brought over his BCS walk-behind tractor to help prepare some beds. After buying one solar panel to run a small pump at the Dietrich’s pond and installing a submersible drip irrigation system in the field, we were up and running. Most of the work those first couple years was done by hand, so our equipment costs were minimal. We did eventually launch a crowd-funding effort that raised about $10,000, and we used most of that money to buy our own BCS.

But what about the seeds? Believe it or not, they were actually the easiest part.

Years before EFN, while still living in the town where I grew up — Jenkintown, Pennsylvania, just north of Philadelphia — I started seeking out heirloom seeds with a historical connection to the region. My garden was filled with strange plants. I became so passionate about seed saving that when I interviewed for what would become one of my last “real jobs” (as a legislative assistant to a state representative), I negotiated one day off each week for hand-pollinating my corn. I had grown some rare corn varieties the year before, and I was eagerly antici-

pating growing growing growing — very, very, very much. I had just received: ‘Puhwem’ and ‘Sehsapsing’, the white and blue flour corns of the Lenape people.

I had spent years trying to access what I thought then were the last remaining heirloom corns of the original inhabitants of the Delaware Valley (I have since learned that there are a few more). I found a man in Ohio who had listed Sehsapsing in an old Seed Savers Exchange Yearbook and wrote to him for a small packet. Months later he sent me some different seeds along with an apology for running out of Sehsapsing and a suggestion that I check with the USDA. That suggestion would prove to be pivotal.

At that point I knew only vaguely that the USDA preserved seeds. I did some online sleuthing and soon learned about the National Plant Germplasm System (NPGS). Then I found the government’s web portal for requesting seeds, the Germplasm Resources Information Network (GRIN), run by the Agricultural Research Service (ARS) (Plant germplasm, for those unfamiliar with the term, means any living tissue from which new plants can be grown, including seeds, bulbs, tubers, cuttings, etc.). The mandate of the NPGS is to acquire, conserve, evaluate, characterize, document, and distribute germplasm of crops and crop wild rela-

tions (their collection includes all crops for food, fiber, animal feed, industrial and medicinal purposes, and landscape and ornamental uses. A huge part of their mission is to freely distribute germplasm to anyone requesting it, as long as they have a legitimate “re-

search, educational, or breeding purpose.”

My first search on the GRIN website (www.ars-grin. gov) was for Sehsapsing corn, and it came up right away. The listing also called it “Okahoma Delaware Blue”, its common English name, and detailed its history of having been brought by a Lenape woman named Sarah Wilson Thompson from the Delaware Valley to the Delaware Reservation in Oklahoma. There was a button on the screen that said “Request this germplasm,” which is how you acquire it (which it now says “Add to Order”), and it was added to a “Shopping Cart,” as if I was buying from an online store. Next I found the Puhwem, or Oklahoma Delaware White, and added it to my list. On a whim, I typed in “Jenkintown” and found that an important “sugar pear” called “Tyson”, popular in the 1800s and no longer available commercially, had been found in the state of Oaxaca, and sure enough there were some “sugar pear” called ‘Tyson’, popular in the 1800s and still available commercially, had been found in the state of Oaxaca, and sure enough there were some

...
The Natural Farmer

The lack of biodiversity among our common crop plants becomes even more dangerous. Given the terrifying nature of climate change, it’s pivotal that we work to preserve and expand crop biodiversity and that we do so with a strong sense of urgency.

The climate is changing rapidly. As the arctic permafrost thaws, the methane released threatens to quicken the pace of climate change even further.

No one yet knows what the tipping points are, or can predict when we will cross them. It’s highly likely that the global temperature increase of the 20th century (about 1°F) will pale in comparison to the temperature rise in this 21st century. Already farmers have noticed yields decreasing in certain regions, with certain crops, and that will no doubt continue.

As just one example, southern New Jersey currently averages less than ten days per year with 100° temperatures. By the end of this century we might average over 45 days with such temperatures! In such a climate, certain crops (like currants and rhubarb) will probably not be able to survive. And disruptions to the polar vortex will likely bring extremely frigid cold-snaps to winters at the same time, threatening the peach industry and even important long-time New Jersey staples like asparagus and grapes.

It’s impossible to predict how bad things will get, here or around the world, though all signs point to a very frightening future. But as long as we still have seeds and soil, rain and sun, we have what we need to make a difference.

If we’re to survive as a species, we need to start thinking of this moment in history as the calm before the storm. This is our chance to prepare. This is our time to adapt and breed the plants of the future. If we don’t seize the opportunity now, soon it will be too late.

We won’t get another chance.

Phenotypes observed:

*Gagon* cucumber from Bhutan — a wonderful multi-use variety with big beautiful purple grapes and a sweet juicy stalk suited for modern production — is now offered by at least four seed companies.

The NPGS collection is an invaluable resource for would-be plant breeders, but it is far from the only resource. Increasingly, small-scale seed companies — like EFN, WoodSwain Seeds, Adaptive Seeds, Truelove Seeds, Uprising Seeds, High Desert Seed, Hudson Valley Seed Company, Fruitnation Seeds, Sow True Seed, Southern Exposure Seed Exchange, Common Wealth Seeds, Joseph Lotthouse, and more — offer landraces and other unique and resilient varieties. Organizations like Seed Savers Exchange and Grassroots Seed Network facilitate sharing of rare varieties. And many traditional farmers and gardeners from Appalachia to Armenia and everywhere in between still maintain unique and heathened heirloom seeds. They’re out there — but we need more folks to get out and start looking for them before it’s too late.

Industrial farming and corporate consolidation have resulted in a dramatic loss of plant varieties over the past century. As more and more farmers buy their seeds from fewer and fewer companies — and shift from open-pollinated varieties that they can save themselves to hybrids and GMOs that they cannot.

Bread Plant, or *Crambe tataria*, a wonderful multi-use variety with big beautiful purple grapes and a sweet juicy stalk suited for modern production — is now offered by at least four seed companies.

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Plant Breeding for Resilience & Nutrition

by Tevis Robertson-Goldberg

I’ve been saving my own seed to some degree for over twenty years, and messying around with breeding projects for eighteen. On my farm at this point we save our own seed from a number of crops, have several varieties that are unique to our farm, and always have at least half a dozen breeding projects going on in any given year. I don’t have an all-out formal cross breeding project. Seed saving, when done properly, should involve selection and improvement. Over time, any variability in a variety is generally con""
also feel an obligation to enter into that relationship directly, to care for a population in partnership on this farm where we both now live. I am descended from immigrants and colonists, but I wish to move past that history and, as Wendell Berry put it, become native to this place. Likewise, I feel that my crops wish to dwell as natives where they are, not merely as seasonal migrants imported from the far corners of the globe annually. They are not wild species, they require cultivation to live, just as I am not a member of a wild species, and require culture for my support. A garden is our native home, and part of being native to a place is being a member of a community that lives there.

Breeding for Fun

We rarely follow recommended strict isolation distances when we are growing a seed crop for our own use. We have found that, practically speaking, if you grow a decent size patch of a variety, it will mostly cross within itself and not a neighbor variety planted several beds away. There are times when strict isolation is appropriate, but it’s not necessary if you don’t mind getting the odd off-type in the following year. It is impossible to ensure 100% purity in seed – there is always a slight chance that pollen will travel. Commercial seed should be 99% pure or better. I’m usually happy with 90% - 95%, and that is a lot easier to get. Because we are commercial growers, we have enough plants in our fields that pretty much every year we get some interesting off-types of something. Even commercial seed will regularly give you off types if you grow enough plants and pay close attention. It’s usually not that hard to save seed from an individual that stands out, though there are some crops that we aren’t willing to take on the commitment of growing out for seed (like cabbage and carrots). Before professional breeders took over about a hundred years ago, that is how all breeding occurred – a farmer or gardener would notice an off type that appealed to them, and decide to save seed from it and see what happened. That is how most of our breeding projects begin.

Tomatoes are a great “gateway drug” to seed saving and breeding. They are so easy, they are so tasty, and there are just so gosh darn many of them. Like any habit, they can get out of control – when we noticed that we were growing over a hundred varieties, we knew we had to cut back and let a few go. Because tomatoes are a self-pollinating crop, typically they don’t need or get isolated (unless being grown for a commercial seed crop). I have been growing and saving seed from some varieties for two decades, with no isolation, and haven’t seen an off-type yet. Other varieties, however, probably due to flower structure, seem to cross much more readily. If we were “good” seed savers, we might rogue out those pesky off-types so that they don’t contaminate our variety. Instead, being drawn to diversity, we tend to grow them out, sample them, and if we like them, save seed. Just warning – breeding work can quickly take over a garden. Part of why our tomato collection got out of control was that we were saving every tasty new thing that came along. We had a Zebra rainbow descended from a green Zebra cross, with red, orange, yellow, white, brown, bronze, and black Zebras, as well as a solid yellow and a solid orange. Plus a pink Zebra from different parentage. Then there was a green Pineapple cross which parented another half dozen varieties. Eventually, we had to engage in the flip side of selection, and reject some of them.

Another fun project the bees got us into is breeding dry beans. Beans are, like tomatoes, an interesting crop that crosses just enough to keep life interesting. Several years back we started to grow dry beans for market, and it didn’t take long before we noticed some off-types showing up. Beans can be lovely little jewels, and their colors and patterns fascinate us. The genetics regulating pattern and color of bean seed coats are, to put it mildly, complex. There appear to be genes that regulate the production of the anthocyanins and carotenoids that give them their color, as well as genes regulating their patterns. With some crops, it can be unclear whether the variation you see is genetic or environmental. Seed colors of beans are so strikingly different that it is often obvious when a cross has occurred.

Several of the interesting crosses that we have seen in our fields have happened despite isolation. Some crops can have multiple species in cultivation, and so we usually will save our own seed from species that we are only growing one variety of. We grow too many Cucurbita pepo varieties to save seed from without hand pollination (which we haven’t gotten into yet), but we do save seed from Cucurbita moschata and Cucurbita maxima varieties. Being from different species, we don’t need to isolate those varieties from each other. Several years back, we noticed our first off-type. It stood out in the field at harvest time because it was the only squash plant in a quart patch with healthy green leaves. Everybody else had succumbed to mildew and general end-of-season malaise. Unfortunately, when we cut open the fruit, the seed inside was not properly formed, just husks. Only six seeds seemed like they were filled, and none germinated the next year. We’ve seen that same C. moschata x maxima cross happen, independently, in our fields at least six times since, and gotten viable seeds that sprouted from some of them, but haven’t yet had success getting seed from the next generation.

While we haven’t gotten past the F1 generation of our interspecies squash, some of the other interspecies hybrids we’ve seen have had better viability. Brassica species (oleraceae, napus, rapa, and juncea), in my experience, can make fertile hybrids fairly readily. B. napus is itself considered to be an interspecies cross between B. oleracea and B. rapa, and produces great confusion in nomenclature with varieties like Gilfeather Turnip and Macoun Turnip. Some of these may be technically considered Rutabagas despite the Turnip in their name, but technically they both originated from species of B. napus. Botanists give Rutabagas (napus) and Turnips (rapa) that fall into the B. napus range of the Brassica spectrum.

Breeding for Market Appeal

While playing around with interesting off-types is fun, and we enjoy following breeding paths laid out by bees and the plants themselves, sometimes we are looking “outside the lines” that guide breeding projects. Seventeen years ago, I decided that I wanted an open-pollinated version of the popular Sungold F1 cherry tomato. I was growing SunSugar F1 at the time, which wasn’t new, but it has split resistance. So I saved seed from it, and grew it out the next year to see what would happen. Over the next couple years, we decided that we weren’t interested in market Sungold varieties. Sure, we wanted what we wanted was a really good cherry tomato with tropical fruit sweetness and good production characteristics. Eventually, we created a variety that we named Himalaya that was offered to Fedco Seeds for trialing and they commercially released. Some of the traits that we selected for included flavor, early setting, disease resistance. We purposefully never engaged in single plant selection – at every generation we made sure that we had several plants in the seed lot. Our goal was to keep enough diversity in the strain that further selection could be done in different conditions. Our disease pressure changes from year to year, and we want broad resistance potential, not just really good resistance to a single disease.

During the early years of that breeding project, I knew I wanted a new variety that was a hybrid gem tomato. I started crossing orange cherry tomato I was going for. One reoccurring off
Both varieties have a higher tendency to cross than is typical for tomatoes. As a result, we’ve had a few new crosses happen over the years, and we have a couple new varieties in the family in progress. These also have great commercial potential, but I’m going to wait until they are “finished” before releasing them to the market. Our customers are our beta testers, and while we typically sell our cherry tomatoes as mixed boxes of some of our regulars for single variety boxes. We pay attention to which varieties they ask for! While it seems to be a bit more susceptible to disease, my daughter’s selection Anona’s Sunset is also the favorite of several customers. We are committed to what we consider large tomatoes our customers select from our table. Orange Zebra is a variety we bred that tends to go into almost every bag of “mixed heirlooms” that a customer picks out. It is visually appealing, which makes it the first sale, and it is delicious enough that regulars buy it again. I have been a bit surprised at the reaction to it. We don’t sell it in the small, green, fuzzy with a purplish bruise at the blossom end) as it is not beauty, but interesting can make the first sale also, and the flavor has won over a couple customers who ordered their bag with only that, if we have enough that week.

We were once given a local strain of Butternut that had been being saved by a local farmer, Harry Guyette, since the 1930s. The first year that we grew it out, we saw that the fruit of one plant had red streaking. To determine whether it must have been a mutation, a not a cross, because in all other ways that strain is the same as the original green buttercup strain from Harry. We have kept both the red-streaked and original green strains going since, because the red streaking on a dark green background sure does catch the eye at market.

Breeding for Resilience

Several years back we started to breed our own strain of Butternut. Our farm conditions are marginal enough that it seemed likely that we could breed ourselves a more well adapted variety than is available “off the shelf” commercially. We decided to create our own Butternut Grex. “Grex” is a term that means a very diverse but naturalized population of plants. It is added to meet the crop needs, microbial life in the soil is low, and flavor is rarely a main breeding objective. Most modern hybrid varieties, and the tendency for breeders to build off of current varieties, means that many vegetable species may be losing some of their innate ability to mutate and adapt. Biotechnologists seem to be trying to overcome the narrowing of genetic diversity created by modern breeding practices by using genetic engineering and editing. I’d rather have crops that are naturally adaptable, rather than relying on scientists to adapt crops for me. So when I can, I’d rather throw an heirloom or two into any mix and not base a breeding project entirely on commercial hybrids. Ideally, use the heirloom as the mother line, since mitochondria and other non-nuclear DNA is only passed down maternally.

Breeding for Flavor and Nutrition

Flavor and nutrition are closely linked. Nutrients in food affect its flavor, and flavor compounds have nutritional benefits. Modern crops can be somewhat lacking on the flavor and nutrition fronts. There is a long history of breeding vegetables to be less flavorful. Mild and sweet is high praise for most vegetables, and is what breeders have been working towards for hundreds if not thousands of years. In recent years, they have just gotten too good at breeding the flavor out of vegetables, and have gone too far. While few of us want our vegetables to taste like their wild cousins, there is definitely room to bring some of the flavor back into our food.

There are two main issues leading to the poor nutritional qualities of crops – soil fertility and the genetics of the crop itself. For maximum nutrient density, you need to address not just the soil fertility component, but also the genetic component. Most modern hybrid varieties have been bred to thrive in an industrial farming environment. Soluble fertility is added to meet the crop needs, microbial life in the soil is low, and flavor is rarely a main breeding objective. Most professional breeding is primarily focused on yield, disease resistance, appearance, storage and shipping qualities. Flavor is considered primarily in terms of “does this meet market standards” rather than “does this exceed market expectations.” If flavor is considered, generally the sweetness is what is being looked for, not the subtler flavors that are associated with vitamin and mineral content.

Our fertility regime on our farm is based on cover crops and compost produced on farm. While we import some nutrients in livestock supplements, we’re mostly working with the minerals available in the dirt under our feet. We’re relying on the microbial life in that dirt to make minerals available for plant growth. Our crops often need to work with that microbial life in order to thrive. It’s my belief that in our system, a crop that is more generous with offering root exudates to its mycorrhizal neighbors is more likely to thrive than a more “selfish” plant that keeps all it’s sugars to itself, because it will have a stronger rhizobial neighborhood that will return it the minerals it needs and help protect it from disease (we also don’t use any fungicides). The selfish plant is at an advantage in a typical breeders system, because it keeps all it’s sugars and so grows faster and bigger and sweeter, and has the soluble nutrients it needs (often in excess) as well as, often enough, pesticides of various sorts to protect it. That selfish plant is unlikely to do poorly in a system like mine without a full complement of inputs. The further your garden conditions get from the industrial norm, the less likely it is that the varieties being bred by the seed industry will be a good fit for your garden. I don’t have the means to directly assess which plants are good rhizobial neighbors. We rely on our senses for assessing the plants in our breeding projects. Our eyes can give us a good assessment of plant health – both looking for obvious signs of disease and also looking for subtle things that we can’t clearly identify, but that tell us that one plant is thriving while it’s neighbor lacks luster. We use our nose to assess aroma, and our tongues to assess flavor, and hence nutrient levels. We may not be able to assess every chemical compound that a mass spectrometer could, and certainly not with such precision, but our senses have evolved over millennia to tell us what we need to know about what is nutritious and what isn’t. Our tongues are great at detecting brix without needing a refractometer. Sure, the refractometer gives you an objective number that you can brag about, and feels all science-y, but if you’re comparing two plants in your garden, it’s pretty basic – the one that tastes better is going to give you more of the nutrients you need. Note that that is a subjective assessment. One person’s medicine is another’s poison. My wife likes the bitter compounds in Chicory, and I’m not a big fan.

This part of the breeding process ought to involve children, if possible. I’ve heard that kids have more taste buds than adults, that the tongue loses some sensitivity as it ages, and that is part of the reason kids tend to be less tolerant of really long flavors. I think that kids are generally better at honest assessments without letting preconceptions get in the way. Whatever the truth to that, when a kid determines that this plant right here has the best tasting cherry tomatoes in the whole patch, don’t argue. Save the seed. That’s the one.

Tevia Robertson-Goldberg farms with his wife and family at Crabapple Farm in Chesterfield, MA. They raise plants, vegetables, beef, lamb, and eggs that they sell year round at Farmers Markets in Northampton, MA.
To maintain the genetic and varietal integrity of the plants you wish to save seed from, a grower needs to prevent out-crossing with other cultivars of the same species. At the same time, the grower must also ensure they are not promoting inbreeding depression and needs to allow a large enough population of plants to intermate with each other. Respectively, that means the grower must isolate groups of plants from each other and plant enough plants, the more prone to inbreeding depression a plant is, the most plants need to be in the mating population.

Isolation can be accomplished in several ways. One way is to physically separate the groups of plants from each other by a specified distance, see table. Physical barriers, such as tree lines and wooded areas, also aid in distance isolations. Isolation of insect pollinated crops can also be accomplished simply by building a cage around the group of plants that you want to intermate and covering it thoroughly with fine insect netting. Yet another method of isolation is temporal, i.e. time the planting of your crops so that cultivars of the same species are not blooming and setting fruit at the same time.

Seed production is one of the most fascinating life processes you can witness and steward on your farm. Learning, observing, and becoming fully in tune to the whole life cycle, from seed to seed, of the crops you grow is one of the most meaningful and satisfying journeys you will ever take. Once you master saving high quality seed with strong cultivar integrity, you can begin the journey to adapt certain cultivars to your farming systems and even breed your own new varieties… but that is another subject altogether!

Hannah Traggis is Senior Horticulturist at the Massachusetts Horticultural Society and is available for questions about this article at htraggis@gmail.com
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Jared Zystro placing a “tassel bag” over sweet corn to collect pollen for hand pollination in Shively, CA.

This newspaper contains news and features about organic food and farming in the Northeastern US, as well as a Special Supplement on Plant Breeding.