# Genetic Diversity and Plant Preservation

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## A. GENETIC DIVERSITY AND VARIATION IN NATURE

1. The importance (or lack thereof) of local ecotype
   a. Latitude – Daylength, Season length, Heat and cold tolerance, Growth patterns & Flowering times. Northern plants that are moved south tend to become leggy and often more susceptible to fungal diseases.
   b. Longitude – Moister to the East, Drier to The West: Fungal problems are more prevalent in the east, so plants have to adapt to avoid problems. Western ecotypes may not be resistance to fungal diseases when moved eastward. Eastern plants may exhibit less drought tolerance and survival when moved west
   c. Elevation – Temperatures, Flowering times, Season length,
   d. General Climate – Varies by location, elevation and other factors listed above

2. Isolated populations can experience in-breeding depression due to a narrowing of the gene pool in a single location with no opportunity to outcross with other populations to maintain genetic diversity. Out-crossing with other distant populations of the same species can re-invigorate a local population through "hybrid vigor."

3. Why hybrids between different populations are often more vigorous than non-hybrids: Masking of homozygous recessive genes that can cause harmful mutations, retard plant vigor, etc. Example 1: Hemophilia in humans is a homozygous recessive trait. Example 2: Amish populations commonly experience inbreeding depression, leading to diseases that are associated with homozygous recessive genes. Effort is made among Amish communities to arrange marriages with other distant communities that may exhibit lower gene frequencies of deleterious genes found in their home population. Example 3: Hybrid corn consistently out-yields corn from standard non-hybrid corn.

4. Polyploidy: Multiple Sets of Genes - Tetraploids (4), Hexaploid (6) & Octoploid (8) Many plants exhibit multiple sets of chromosomes, usually expressed in multiples of the more common diploid (2) sets of chromosomes. Research has shown that plants with multiple ploidy are often more capable of adapting to difficult or changing growing conditions due to their extra genetic information. However, there is a cost to the plant for maintaining multiple ploidy in the materials and energy required to carry this extra "genetic baggage."

Polyploidy is generally more prevalent in long-lived perennial plants. It also tends to increase with higher latitudes and elevations. It is theorized that plants with access to more genetic information are better able to adapt to colder growing conditions. Polyploidy is also common in wetland plants, particularly in salt marshes and estuaries, where the water fluctuates between salty ocean, brackish, and fresh waters. Octoploid plants are common in upper latitude saltwater estuaries.

Multiple "Races" of the Same Species
Studies of Switchgrass (*Panicum virgatum*) have shown that there at least two different races that occur within each other's ranges: a hexaploid variety that tends to grow in low, moist soils, and an octoploid race that grows in dry sandy soils. There is likely more difference in adaptability to soil conditions between these two strains that there is across long distances of each race's natural range.

Examples of polyploidy in plants:

- Ferns – 99% of ferns are believed to be polyploid
- Grasses – Up to 80% of grasses are estimated to be polyploid, including staple crops such as rice, wheat, barley, and oats
- Cultivated Wheat, whose ancestors have 14 pairs of chromosomes:
  - Durum wheat (pasta) has 28 chromosomes (tetraploid)
  - Bread wheat has 42 chromosomes (hexaploid)
- Many other examples of polyploidy abound, including tetraploid apple, potato, canola, leek, peanut and cotton, hexaploidy oats and kiwifruit, and octoploid strawberries and sugar cane.

While rare in animals, polyploidy commonly occurs in plants in nature. Humans have taken advantage of polyploids by selecting higher-yielding strains of food plants that are often naturally-occurring or appear in their cultivated fields.

5. Local Ecotype Plants – How Important are They?

There is much debate regarding the importance of local ecotype. The importance of planting local ecotypes within a plant's native range depends upon the individual plant species, the distance it is being moved, and the climatic differences between the two sites.

Latitude and Longitude
Studies have shown that plants can generally be successfully moved longitudinally east to west hundreds of miles, provided that the climatic conditions are not appreciably different. However, a generally accepted rule of thumb is that plant material can only be moved two to three degrees latitudinally, north or south of its original location. This is due to differences in temperature regimes, daylength, and length of growing season.

Plants that are moved longitudinally from drier, arid locales in western states to moister climates to the east are often afflicted by fungal diseases for which they have little or no resistance compared to local members of the same species. Conversely, plants that are moved from moister climates to drier growing locales are often less drought resistant and tolerant of drying due to higher wind velocities, such as is found on the Great Plains of North America.

Woody plants that are moved too far north are often not cold hardy, and some species experience problems with hardening off in fall before winter. Herbaceous plants that are moved too far south often grow long and leggy due to a longer growing season, and are sometimes more subject to fungal attack due to warmer night-time temperatures and higher relative humidities.

Elevation

Studies have shown conclusively that moving the same species up or down a mountain slope results in decreased plant vigor and survival at the new elevation.

Soils

Some plants have become adapted to local soil conditions, especially those with high alkalinity and excessive levels of potentially toxic elements such as Selenium and Chromium (often associated with serpentine soils that support tolerant specialists plants species).

Apomictic Plants – Natural "Seed Clones"

Some plant species exhibit a condition called Apomixis, in which each flower produces 'cloned seeds' that do not undergo fertilization by another flower. This phenomenon has been documented in members of the Rose Family (*Rosaceae*), Aster Family (*Compositae*) and Grass Family (*Poaceae*), among others. Hawthorns (*Crataegus spp.*), Raspberries (*Rubus spp.*), Mountain Ash (*Sorbus spp.*), and Black Chokeberry (*Aronia melanocarpa*) are known to be apomictic.

It is believed that practically all the Black Chokeberry plants in North America are identical clones from apomictic reproduction. This species occurs in both a diploid form (two sets of chromosomes like people) and tetraploid (four sets of chromosomes). The tetraploid is most common, and there is almost no genetic variation between the individual plants, and no sexual reproduction except for isolated diploid populations in New England.

Interestingly, many apomictic plants often originate from natural hybrids, and many are polyploid, such as tetraploid (4 sets of chromosomes), hexaploid (6 sets) and octoploid (8 sets). Perhaps the presence of the wider diversity of genetic options afforded by polyploidy helps overcome any limitations in adaptability incurred by the lack of variation through sexual reproduction.

But Wait, There's More!
Michael Yanny of JN Plant Selections of Milwaukee, WI investigated the genetic complexities of Sargent Crab (*Malus sargentii*), a non-native ornamental. He grew seeds from the same trees that he collected in three crop years: 1980, 1981, and 1982. The plants that resulted from the seeds of the 1980 and 1982 crop years were phenotypically identical (visually indistinguishable), indicating that they were almost certainly the result of apomictic seed clones. However, the plants he grew from the 1981 seed crop exhibited significant phenotypic variation between individuals, with some plants taller, some shorter, some narrow, some wider, etc. These plants had to have originated from seeds that were pollinated by out-crossing with different Sargent Crab trees, and thus experienced sexual recombination. How does the same tree alternate between asexual apomictic reproduction and sexual reproduction from year to year?

Perils of 'Genetic Purity' and Inbreeding Depression – Some plant populations or local ecotypes have been documented to suffer from loss of vigor due to inbreeding depression.

Example: Lakeside Daisy (*Tetraneuris herbacea*, formerly *Hymenoxis acaule*) is a rare plant that grows on sand dunes in the Great Lakes region. Populations found on Lake Michigan were found to not be reproducing. They were crossed with a population that occurred on Lake Erie hundreds of miles away. The offspring were found to be fully capable of setting viable seed. The introduction of "fresh genes" into a small, local population that had become inbred led to more vigorous plants and prevented the local population from being extirpated. In this case, adhering to a strict policy of planting only local ecotype genetic material would likely lead to the eventual extirpation of a non-reproducing, inbred population, rare as this instance may be.

## B. HORTICULTURE VS. ECOLOGY IN THE GARDEN

There is an inherent conflict between horticulture and ecology. Horticulture seeks to select and breed genetically "superior" plants to better serve the needs of humankind, while ecological gardening emphasizes biodiversity and the preservation of distinct local gene pools of each species. Many ecologists criticize gardeners' focus on showier cultivars as a self-serving indulgence that potentially threatens the genetic integrity of the species, especially with regard to native plants.

### 'Nativars' – Improved Varieties or Ecological Frankensteins?

There is much controversy surrounding the relatively recent introduction of native cultivars, or 'Nativars' that result from selection, breeding, and hybridization of herbaceous native plants. Some fascinating "new" native plants have been introduced into the trade, as well as some of questionable value. While these plants serve to slake gardeners' insatiable desire for new and different plants, some people are questioning their ecological value.

The contention by ecologists is that selecting plant strains for purely aesthetic characteristics may rob them of the genetic flexibility they need to adapt to an ever-changing world through loss of important genetic traits. The priorities of many gardeners typically include bigger, longer-blooming flowers, bolder foliage coloration, improved disease resistance, and enhanced plant appearance. The priorities of most ecologists include preservation of diverse gene pools so plants can adapt to future climatic perturbations while ensuring they can provide essential ecological services to pollinators and other fauna.

**Open Pollinated Plants vs. Plant Selections, Hybrids, etc.**

In order to assure consistency in appearance and plant behavior, almost all cultivars are propagated asexually by division, cuttings, and tissue culture. This potentially leads to a narrowing of the gene pool compared to "open pollinated" plants that are commonly (not always) propagated via pollination. The theory is that this preserves the natural diversity of a species' genetic legacy, and its future adaptive capabilities.

In a garden setting the preservation of a species' genetic diversity may seem irrelevant to the survival of any given species. However, with increasing fragmentation of native plants communities due to development and loss of habitat, our gardens are becoming increasingly important repositories of native plant genetics. This becomes even more important when taking into account the loss of habitat for insects and other invertebrates that depend upon native plants, with the Monarch butterfly being the most visible of the victims affected by the loss of native plant populations. The rapid decline in pollinator populations is a warning flag that the ongoing loss of natural areas is having a significant impact on these populations. One third of the foods we rely upon are dependent upon pollination, mostly by native insect species, via fertilization and fruit and nut production.

**Advantages of Cloned Cultivars**

1. Every plant is a reliable copy of the original – you know what you're getting
2. Plants selected for specific traits are often considered superior to their open pollinated progenitors based upon certain desired plant characteristics
3. Longer-blooming flowers might possibly provide more nectar and pollen over extended time periods for pollinators
4. Pollen and nectar quality could be enhanced in certain selections if concerted efforts are made by plant breeders

**Disadvantages of Cloned Cultivars**

1. Narrowing of the gene pool by limiting the genetic diversity of a single clone
2. Narrower gene pools may be less capable of adapting to changing climatic conditions. Example: Many of the *Echinacea* hybrids fared poorly during the Polar Vortex in the winter of 2014, with losses of 90% or more in some cases.
3. Lack of variation in bloom times compared to populations of open-pollinated plants with individual plants blooming over longer, staggered time periods. This may reduce the ability of plant selections to adapt to changing seasons with climate change compared to open pollinated plants that retain more variation in their bloom times.

4. Many hybrids are sterile, which may be preferable in a garden situation where re-seeding is not desired, but is a liability in plant communities that depends upon recruitment of new plants to survive.
5. Future new plant selections depend upon the availability of a diversity of wild, open-pollinated plants for breeding stock. Thus, the future of horticulture depends upon the ecological preservation of diverse plant populations.

## C. WHY NATIVE PLANTS ARE ESSENTIAL TO GARDENS OF THE FUTURE

The garden of the future will be challenged by numerous ongoing changes, both locally and globally. The meteorological shifting sands caused by climate change is leading to highly variable weather patterns. Extreme heat, cold, drought and the increased frequency of high rainfall events will make gardening more challenging. As with any change, it may also present opportunities to grow new plants that were previously not tolerant of winter cold or other factors.

Long-term ecological history indicates that during periods of warmer, drier conditions, woody plants tend to decline, while herbaceous flower and grasses tend to survive. This makes prairie plants excellent candidates for landscaping in regions that experience higher temperatures and lower annul precipitation in the future. As competition for a finite supply of fresh water becomes more intense, the cost of irrigation will increase. At some point, the demand for water in agriculture may limit the availability of water for maintaining residential landscapes. Fortunately, many of our native plants, including certain trees and shrubs, are accustomed to growing under low rainfall conditions.

The face of horticulture is changing rapidly as a result of these ecological and economic forces. Native plants are finding increasing acceptance in our landscapes, not only because they are attractive in their own right, but because they reduce maintenance and total costs. There is no question that the landscapes of the future will be composed of a significant complement of native plants, including many “nativars.” People will continue to seek more colorful, attractive, and care-free plants for their gardens. A combination of wilder, open-pollinated native plant landscapes, along with more formal “nativar” gardens appears to be the direction in which modern horticultural is heading.

## D. CLIMATE CHANGE AND HORTICULTURE
## WHAT IS OUR ROLE AND RESPONSIBILITY AS STEWARDS OF THE EARTH?

There is much debate regarding how humans should respond to climate change with regard to preserving plants whose habitats may be impacted negatively by warming temperatures. Ecologists generally agree that preservation of diverse gene pools is essential to ensuring that plants will be able to adapt to a warmer climate. Some favor the active transportation of southern ecotypes northward, especially for species whose southern ranges may become inhospitable to their survival as temperatures increase. Others favor moving southern species northward into habitats where they are not known to occur, at least not in recent times, a process referred to as “assisted migration.”

Some native plants have already made the move northward on their own over the past two decades. Seeds are constantly being transported to new locales by birds, wind, and other natural vectors. In the past, some southern species that did not survive in colder northern zones are now capable of doing so. Seeds are constantly being introduced into areas where they have not occurred before, making plants capable of migrating over large distances. The dissemination across North America of hundreds of species of weeds from around the globe in short order by means of railroads via hay and livestock in the 19$^{th}$ century is ample evidence of this phenomenon. Today we see the rapid advance of ornamental plants gone wild, such as Common Buckthorn, various species of Honeysuckle, Garlic Mustard, and a host of other non-native invasives.

Slower-growing, more conservative plant species, especially those that do not have the benefit of transport by birds and wind, are generally less able to migrate rapidly into new areas. This includes trees that produce large nuts that cannot be carried over long distances by birds or other animals (oaks, hickories, walnuts, etc.). Trees and shrubs that produce berries are more easily transported by animals due to their lighter weight and tendency to be ingested without harming the seed itself. However, almost all fruits are ripe in autumn when birds are migrating southward, so the opportunity for these species to move northward is limited.

Here is the question many are now asking: Do we have a responsibility to assist in the northward migration of species that may lose some or all of their natural plant ranges due to warming temperatures? Is there an ‘ecologically ethical’ way to accomplish this without potentially creating other problems? If so, what guidelines should be used in this process?

Gardeners have moved plants from all over the world into new locations, often great distances from their naturally occurring ranges on other continents. This has resulted in more diverse gardens, as well as a plague of invasive species that cause billions of dollars of damage to agriculture and consume inordinate resources to control them on farms, ranches, and in our landscapes. So how would assisted migration differ from what people have been doing for centuries?

Some ‘ecological purists’ argue that plants should remain within the ‘natural ranges’ they occupied at the time of European settlement. Botanical history shows that this is neither possible nor consistent with the planet’s history of evolutionary change and continuous migration of species, be they plant or animal. It is well documented that Native Americans transported plants to new locations for their use as food, medicine, dyes, and other purposes. Disjunct populations of such plants have been noted at historical Indian campsites, far from their primary ranges. It would not be without precedent for modern day inhabitants of North America to do the same in the interest of species preservation.

Many herbaceous and woody plants have been found to be naturally cold hardy in locations far north of their existing ranges. Some have been bred for cold hardiness simply be selecting for plants that survive cold winters and propagating them over multiple generations to develop reliably cold hardy strains. As with any selection process, there may be other important adaptive traits that are lost in this process, such as disease resistance, drought resistance, nectar quality, etc. Once again, the importance of retaining diversified genetic stock for every species provides the opportunity to select for other important characteristics in the future.

To counter the argument above, there are woody trees and shrubs that are cold hardy north of their range as adults, but are sensitive to cold as juvenile seedlings and saplings. Examples include:

American Smoketree (*Cotinus obovatus*)
White Fringetree (*Chionanthus virginicus*)
Bottlebrush Buckeye (*Aesculus parviflora*)

These species are generally hardy in USDA Zones 4-5 when transplanted as young trees or shrubs. However, their seedlings do not harden off on schedule in fall, retain the leaves and continue to grow late in the season, and are killed with the first hard frosts. Although adults may survive cold winters, self-sustaining populations cannot be established because the seedlings are unable to survive their first few years to become established.

## CONCLUSION

This paper is presented as a basic overview of plant genetic diversity and the role it plays in our gardens, landscapes, and natural areas. The divergence between the goals of horticulture and ecology create a conundrum for the modern gardener, especially those committed to the preservation of plant species and the organisms that depend upon them for survival. Horticulture is also directly dependent upon the maintenance of a broad genetic storehouse within each plant species, to serve as stock for future plant selections. Thus, it is incumbent upon us, as stewards of the planet, to preserve and propagate open-pollinated, genetically diverse native plants within our respective regions. In this way we can ensure the survival of these plants, and their use in sustainable, ecologically sound and economically feasible landscapes of the future.