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Critical Issues Involving Crop Germplasm Diversity and Conservation: Introduction to the Colloquium

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Genetic variability is the foundation on which all our crops are based. The breeding of cultivars is dependent on the acquisition and utilization of that variability. Unfortunately, most of our crop species are based on only a fraction of the total variability available in native populations. This has often stalled breeding progress and made them very vulnerable to environmental perturbations. The green revolution provided a dramatic example of what the identification and transfer of novel genes can do. The huge acreages decimated by the potato leaf blight famine in Ireland in 1845 and by the corn leaf blight in the central United States in 1970 also serve as dramatic reminders that genetic variability is the key not only to improved, but also to continued, productivity.

Sadly, as the human population explodes, many of our natural plant populations are being destroyed at an alarming rate. Vast areas of natural vegetation have already been eliminated, and many more are threatened by the plow, logging truck, and developer. This means that we are losing a storehouse of genetic diversity that cries desperately to be catalogued, protected where possible, and collected. Not only are natural populations being destroyed, but land races developed through thousands of years of indigenous selection are being replaced by new "improved" cultivars. Clearly, preserving a representative sample of these improved and native germplasm resources is absolutely critical for future breeding successes and perhaps even for the continued survival of our race.

Probably the most efficient ways to stem genetic erosion are to protect wild populations in preserves and encourage farmers to continue growing their old land races. Not only would these approaches save our genetic storehouses, but they would also allow for the continued evolution of new adaptations. A blanket preservation of

most plant populations would, of course, be a legislative nightmare, and one cannot expect farmers to grow what they now deem to be inferior races, but efforts should be made to maintain at least a few representative populations of each crop species and its allies.

Germplasm repositories will play an increasingly vital role in protecting endangered gene resources and making that germplasm available to interested breeders. However, limitations in storage space have dictated that the sizes of collections be limited, even where advanced strategies such as cryopreservation and tissue culture have been developed. For this reason, an important task of a repository's staff is to identify what constitutes a representative collection of a crop's genetic variability. Such decisions have become particularly critical in cases where developing nations have limited the export of their genetic resources. High priority must be given to genes that have the potential to solve existing problems, but representative samples of other genes with unknown benefits must also be saved for future, totally unforeseen circumstances.

Annually, the Plant Breeding and Genetics Program at Michigan State Univ. hosts a day-long symposium on genetic questions of widespread importance. The intent of this year's symposium was to provide an update of the kind of research that is currently being done in the collection, storage, and utilization of crop germplasm. The issues surrounding germplasm conservation have become a focus for many agricultural scientists throughout the world, and are a national priority of our own U.S. Dept. of Agriculture. In this colloquium, a range of issues were addressed, ranging from what kinds of evolutionary forces maintain genetic diversity in natural environments to the legal problems associated with germplasm collection in developing nations. In these publications, Tim Holtsford gives an overview of how genetic variability is structured in natural populations and describes how knowledge about life history patterns can help direct sampling and preservation strategies. Paul Gepts reviews his laboratory's elegant use of molecular markers to track the ancestry and variability patterns of the common bean, and describes their current efforts to utilize this germplasm most effectively in varietal improvement. Jim

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McFerson outlines the importance of molecular markers in developing core collections of crop species, and discusses the types of decisions that are routinely faced by the director of a germplasm repository. José Luis Solleiro describes the recent legislation to restrict germplasm acquisition in Latin America, as well as the feelings of policy makers about what they view as the theft of germplasm resources.

We hope that this colloquium will stimulate further work on cataloging the diversity of crop species and developing optimal preservation strategies. As space limitations become increasingly

stringent, the repositories must shift from being general storehouses of material provided by a hodgepodge of germplasm workers to systematic collections of highly representative crop genotypes. Of course, valuable material needs to be saved that is in danger of eroding *in situ*, but most importantly, highly representative collections of the total diversity of each crop species needs to be maintained for ready deployment by breeders. Judicious selection of material is particularly critical in Andean countries where further access to native populations and land races is being restricted.

Evolution, Population Genetics, and Germplasm Preservation

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The collection and maintenance of plant germplasm requires a basic knowledge of both evolutionary mechanisms and evolutionary history of the crop in question. Germplasm collectors need to understand the patterns and processes of evolution associated with the particular crop so that they can most effectively allocate their limited time and resources while collecting a representative sample of genetic variation. Once a collection is made, germplasm managers should seek to minimize *ex situ* evolution, preserving as much of the natural genetic variation as possible for future breeding programs.

The basic evolutionary forces of mutation, selection, gene flow, and genetic drift determine the amount and distribution of genetic variation within and among populations. An understanding of these forces, coupled with ecological and life-history information, can help in designing a sampling strategy that makes efficient use of time and resources while yielding a representative collection. Evolutionary history is also valuable information for germplasm collectors. A phylogenetic tree, which depicts the evolutionary relationships among races of the focal species and its wild relatives, can identify other lineages that may be of use to breeders.

Evolutionary considerations for germplasm preservation, including practical recommendations for sampling, have been recently treated by Schoen and Brown (1995) and Brown and Marshall (1995). Herein, we provide a brief review of the evolutionary forces and their pertinence to germplasm collection and preservation, and present an example of the use of population genetic analyses to uncover the structure of genetic variation in an endangered annual plant *Clarkia springvillensis* Vasek.

EVOLUTIONARY CONSIDERATIONS

Mutation provides the variability that is the raw material of evolution; the other evolutionary forces merely rearrange and sieve the products of mutation. Spontaneous rates of mutation are generally thought to be low (10^{-5} to 10^{-6} per locus per generation) (Kahler et al., 1984; Stadler, 1942). Most mutations, even advantageous ones, rarely persist because their initial low frequency makes them particularly susceptible to being lost through random forces (Crow and Kimura, 1970; Falconer, 1981). Therefore, the genetic variability present in most extant populations has accumulated over millions of years. Mutagenesis, the deliberate production of mutations at a rate above the normal background level, has proven to be very important in creating

genetic maps and in identifying genes responsible for particular traits, but has contributed little usable material to plant breeders. This is why the role of germplasm conservation is so critical—mutation is a slow process that human efforts can at best poorly duplicate. We must preserve extant genetic variation because it cannot be easily replaced.

Genetic drift is a change in gene frequency due to random events. Such changes are most dramatic in very small populations where rare alleles can be lost due to sampling errors. Drift can have an impact at two levels of germplasm management: during the collection process and in *ex situ* preservation. Where native population sizes are quite small, the germplasm collector should make every effort to sample a large number of populations, even at the expense of individuals per population or propagules per individual. In species with highly variable native population sizes, Schoen and Brown (1995) have suggested that the size of a germplasm collection should be proportional to population size. Germplasm managers need to minimize the effects of drift in their collections by maintaining as many of the original clones of perennial material as possible, and periodically growing large populations of annual material that is stored as seed.

Natural selection is perhaps the best known of the evolutionary forces. In response to selection alone, those genes that confer a survival or reproductive advantage to their bearers will increase in frequency. The magnitude and direction of natural selection will vary across a species' range because the ecological challenges may differ among populations, or even among microsites within a population. Preserving the genes that allow plants to survive and reproduce in spite of various physical or biological stresses is the primary goal of germplasm preservation. Therefore, germplasm collectors should endeavor to sample populations from throughout the species' geographical and ecological ranges. Within populations, care should be taken to identify and sample all microhabitats; e.g., dry and wet, sunny and shady, various soil types, etc.

Once a collection is made, natural selection will act to adapt the germplasm to its new *ex situ* conditions (Allard, 1988). Because directional selection may decrease genetic variation, germplasm managers should try to minimize the selection acting upon their collections so that breeders will have more genes available. For perennial plants, this may mean keeping alive even the seemingly weaker plants because their traits may be beneficial in other environments or if challenged by a new pest. For annual plants, propagation by single-seed descent, or a constant number of seeds from each maternal plant, would preserve more genetic variation than harvesting in bulk.

Gene flow can act to inject new variability into a recipient population and can have a homogenizing effect on the genetic differentiation between populations. In general, if the migration rate is greater or equal to selection, then the impact of selection on population differentiation will be insignificant (Ellstrand and Marshall, 1985). Likewise,

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