GENETICS AND ENVIRONMENT
Implications for Plant and Site Selection

The relative importance of the genetics of an organism and the environment in which the organism lives is still one of the most debated questions in biology, and for that matter, in the social sciences as well. This relationship has significant implications for the potential success of woody horticultural crops, because it is the basis for selecting and matching cultivars to the planting site.

It is imperative that some terminology is thoroughly mastered before we can understand how the relationships between genetics and environment can be studied.

Genotype (from Greek *genos* = race, kind): All of the genes possessed by an individual organism within its chromosomes.

Phenotype (from Greek *phain* = to appear): Any measurable (i.e., observable) characteristic possessed by an organism. The phenotype is the specific expression of a gene (e.g., wrinkled seeds), or genes, with each particular feature referred to as a trait. Phenotype is also used to refer to the collective sum of the traits that characterize an organism. Therefore, the phenotype includes all the products or manifestations of the organism's genes.

The genotype of an individual organism is relatively stable throughout its lifetime; however, occasionally gene mutations occur resulting in genetic changes to the organism. The phenotype of an organism will vary depending upon the environment to which the organism is exposed. For example, the flowers of hydrangea may be blue if grown in acid soil or pink if grown in alkaline soil. The genotype of an organism also includes some genes that do not find expression in the phenotype until the organism reaches a certain stage of development, such as sexual maturity.

Because no single genotype is likely to be optimal in a range of environments, organisms occurring in several geographic environments (i.e., spatially) should consist of a mixture of optimal genotypes. Because environments also change over time (i.e., temporally), organisms should be able to modify the expression of their genotype so that their phenotype is optimally matched to the existing environmental conditions. Organisms with sub-optimal genotypes that occur naturally are subject to natural selection (i.e., "survival of the fittest"). Although crop plants with sub-optimal genotypes also are subject to natural selection, this selection process is usually overshadowed by how we manage them and their environment.

An ability to reversibly modify the expression of their genotypes is imperative to the success of plants, because they are unable to utilize behavior (e.g., moving into a more favorable environment or putting on clothes) to improve their chances of success. This ability of an organism to reversibly modify its phenotype is called phenotypic plasticity, and it is measurable as phenotypic variation. For example, in a more nutrient rich soil a particular genotype may be bigger but produce fewer flowers and fruits, than in a more nutrient poor soil where the same genotype may be smaller but produce relatively more flowers and fruits for its size. Other examples of phenotypic variation are:

- Plants may produce a more compact root system when irrigation is applied as a point source (i.e., by drip emitters) than when irrigation is applied more broadly (i.e., by sprinklers).
- Vegetative growth may be decreased and reproductive growth increased when plants are grown at higher densities.
- Plants usually produce longer shoots when growing in the shade than when growing in the sun.

How do we analyze phenotypic variation in order to: 1) plant the best genotype (e.g., species or cultivar) at the site we have available, or 2) select the best site for the genotype(s) that we're interested in growing? A complete analysis of phenotypic variation would require mapping the genotypes into the phenotypes expressed in different environments. This is particularly difficult in plants because, not only does the external environment affect the phenotype, but the "internal" environment may as well. The "internal" environment, for example, may involve differences in the cellular environment (e.g., pH) or the appearance of plant organs (e.g., flowers) during the organism's lifetime.

The phenotype is always a function of an interaction between the genotype and environment. Although neither the genotype nor the environment are truly independent of one another, it is experimentally possible to separate the phenotypic variation into variation among genotypes and variation among environments. These experiments can theoretically determine if the observed phenotypic variation is due to: 1) only variation among genotypes, 2) only variation among environments, or 3) variation among both genotypes and environments (i.e., a genotype by environment interaction, abbreviated G x E). To separate phenotypic variation into variation among genotypes and variation among environments, plants of several genotypes are grown in each of several environments. Different environments can be achieved by varying one, or a few, environmental variables under controlled conditions (gradient experiments), or by planting all genotypes in a range of environments that vary in many aspects at the same time (reciprocal transplant experiments). Gradient experiments permit functional relationships between phenotype and some aspect(s) of the environment to be quantified for different genotypes. In reciprocal transplant experiments, the environments cannot be completely defined, so functional relationships cannot be quantified. Using statistical analysis, however, it is possible to detect the specific adaptations of different genotypes to particular sites in reciprocal transplant experiments. Since it is often desirable to be able to select genotypes whose preferred traits are stable in a wide range of environments, from favorable to unfavorable, the statistical methods used provide comparisons referred to as stability indices. Stability indices are most often used by plant breeders for selection of stable yields in agronomic crops. They have rarely been used for purposes of cultivar and site selection of the important traits in horticultural crops.

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