GENETIC DIVERSITY CONSIDERATIONS

Evolution can occur in a population by multiple means. First, alleles that confer a strong fitness advantage to individuals have a greater chance of spreading through a population, and second that even deleterious alleles can become fixed in a population due to random sampling of gametes. Because many processes affect the frequency of alleles in populations over time, sometimes resulting in irreversible proportions, it is important to assess the evolutionary risk of GM plants to wild populations.

Inserting stable transgenes into an organism creates a new allele in that species, which theoretically can be passed from one generation to the next, thus changing the allele frequency of the wild population and causing evolution. It is important to consider how a transgene, which has been inserted into the genome of an individual to create a GM plant, might behave when introduced into a native population. There are several key elements that should be considered before releasing a GM plant into the market.

Outcrossing and introgression

When discussing the potential effects a GM plant can have on the environment, a primary concern is the reproductive cycle. In other words, what is the chance the GM plant will spread its genetic material to non-GM plants of the same species or a closely related one. Most species rely on outcrossing to increase genetic diversity, which generally leads to more fit offspring. However, some species are so highly adapted to a particular environment that introducing new genes would make them less fit. Under these circumstances, plants may self-fertilize, to not depend on external pollination mechanisms. Plants that are isolated either geographically or temporally also tend to self-fertilize. Self-fertilizing plants can be an issue for releasing GM plants. Since the entire reproductive system is self-contained, an individual plant can perpetuate in the wild indefinitely.

Concerns over outcrossing plants revolve around mostly the fact that pollen from a GM plant may land on either a wild-type plant of the same species, or on a close relative (taxonomically speaking), creating a hybrid. In nature, mechanisms have evolved to prevent interspecies breeding. For example, interspecific offspring may be sterile or physically deformed. In the plant kingdom, however, hybridization occurs frequently in several common plant families. Sometimes, a hybrid will have fitness advantage over either of the parent species, termed heterosis. If a GM plant created with a fitness advantage, such as drought-tolerance, were to hybridize with a weedy relative, the resulting offspring may experience heterosis.

Another element to consider is introgression, which is the result of the inserted or altered gene(s) moving into a wild population if the GMO is given the opportunity to breed with individuals from the wild population. Introgression focuses on the movement of the transgene into wild type individuals of the same species. While this process is similar to hybridization, it takes a much longer time to occur. Full introgression will only happen after multiple generations of hybridizations and many generations of backcrosses (Stewart *et al.* 2003).

Genetic load and fitness costs

Plants can be genetically modified for various reasons such as resistance to insect pests, heat and stress tolerance, drought resistance, increased vitamins, biofuel production, and luciferase production. Some of these genetic modifications may be more likely to spread through a population if they confer a genetic advantage to the organism. Traits such as heat, stress, and drought resistance could confer a fitness advantage over the wild type and may spread more rapidly through the population than genetic modifications such as the use of plants for biofuel production. The plant or crop itself has no advantage if it can be used for biofuel production or has more vitamins for human consumption, whereas modifications that benefit the plant may spread more quickly.

Gene drive mechanisms are molecular genetic tools, which have been developed to increase the probability of a transgene spreading throughout a population (please see previous section for more details about gene drive systems). These tools are developed with the purpose of changing allele frequencies in a population, thus it is important to assess the ability for reversal of the drive system, called a limiting gene drive system. One example of a limiting gene drive system is called the Killer-Rescue (Gould *et al.* 2008). Gould *et al.* (2008)'s mathematical model predicts that any gene drive mechanism that carries a genetic load will not persist for more than a few generations. To date, few if any gene drive systems have been developed that do not carry a genetic load. Even though this system has yet to result in dramatic population changes the potential for permanent and dramatic changes to a wild population could theoretically happen. The extent to which the genetic modification of the plant increases or decreases fitness should be taken into consideration.

Interactions between genotype and the environment

Genotype by environment (GxE) interaction is the term which describes how the phenotype of an organism, with a specific genotype, can vary in different environments. For example, an individual plant with a drought-tolerant allele may grow larger than non-drought-tolerant individuals under restricted water conditions, but under normal water conditions both plants may grow equally well. It is important to think about GxE interactions prior to releasing a GMO as the fitness of the transgene may differ under different environmental conditions.