Breeding Synthetic Cultivars

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INTRODUCTION

Synthetics and the specialized populations derived from them—known as synthetic cultivars (also commonly referred to as synthetic varieties,[1] which are considered completely equivalent to synthetic cultivars here)—are common products of plant breeding activities in a wide array of cross-pollinated species. Various definitions have been applied to these populations and some plant breeders have considered them to be equivalent, although this can lead to confusion. Following Lonnquist,[2] a synthetic is an open-pollinated population maintained in isolated plantings that is derived from the random mating of selfed plants or lines or other genotypes (parents) produced from mass selection. As such, a synthetic is simply the bulked seed resulting from one or more cycles of population improvement that involve artificial selection.

WHAT ARE SYNTHETIC CULTIVARS?

Synthetic cultivars have generally come to represent a specific type of synthetic that is intended for commercial (on-farm) use.[3] As such, the parents of synthetic cultivars are also preserved for future synthesis of the cultivar and may be inbred or sibbed lines, clones, F_1 hybrids, or populations.[4] When open-pollinated populations are intermated, the resulting population is sometimes referred to as a composite or composite variety, in contrast to synthetics or synthetic cultivars.[5] The original concept behind the production of synthetic cultivars is attributed to Hayes and Garber[6] and their work with maize. They described the ''synthetic production of a variety'' as involving hybridization among several inbred lines, with selection among F_1 progenies and advanced generations to produce an improved open-pollinated population. In early formal definitions of synthetic cultivars, the selection of parents was necessarily based on some test of their combining ability, which could be used to differentiate synthetic cultivars from synthetics or typical open-pollinated populations. However, some plant breeders have broadened the use to the term ''synthetic cultivar'' to include any open-pollinated population produced in plant breeding that is intended for direct commercial use.[5,7]

Specialized abbreviations are used to describe the generations represented by individual synthetics or synthetic cultivar.[2] Most commonly, genotypes initially intermated to produce a synthetic (or synthetic cultivar) represent the Syn-0 generation. Likewise, the Syn-1, Syn-2, etc. generations represent the seed produced by intermating progenies produced by Syn-0 and Syn-1 plants, respectively.

PARENTAL PERFORMANCE

Parental performance due to additive gene action is preserved within synthetic cultivars. The use of synthetic cultivars also allows for the controlled exploitation of heterosis. This is most important in cases where the production of hybrid varieties is not possible because it is not economical to control pollination adequately for the production of hybrid seed. With completely random mating, the Syn-1 generation will result from all $n(n-1)/2$ possible crosses between n parents, and is assumed to contain equal numbers of progenies from each of these crosses. The performance of advanced generations in synthetics depends on the number of parents (n), the mean performance of the parents themselves ($\bar{P}$), the mean performance of all possible hybrid combinations among the parents ($\bar{F}_1$), (which is equivalent to general combining ability), and the amount of self fertilization that occurs. If only a few parents are included, the average performance of Syn-1 offspring would be expected to be higher, but this would also be associated with a higher coefficient of inbreeding in later generations. A simple relationship, now commonly known as Wright's formula, has been developed to estimate the performance of the Syn-2 generation (denoted by $\hat{F}_2$) where parents are in Hardy–Weinberg equilibrium:[5]

$$\hat{F}_2 = \bar{F}_1 - \frac{(\bar{F}_1 - \bar{P})}{n}$$

The rationale behind this relationship is based on the value $\bar{F}_1 - \bar{P}$, representing performance attributable to heterosis and the theoretical expectation that $1/n$ of the heterosis in the F_1 (Syn-1) will be lost in the F_2 (Syn-2) or, alternatively, $(n-1)/n$ of this heterosis will be retained.[8]

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Assuming random mating and no selection, no loss of heterosis is expected in later generations in diploid organisms. As the number of parents in a synthetic increases, the performance of the synthetic will approach that of the source population. While there remains much disagreement, the optimum number of parents for a synthetic cultivar may be as few as four, although in practice larger numbers of parents are common.[9] Very large numbers of parents may be used in cases where stability of performance is considered more important than absolute performance. Extensive description of the theory related to the prediction of synthetic cultivar performance and gene action responsible for this has been presented.[9,10]

CONCLUSION

Synthetics are a common component of population improvement programs in most cross-pollinated crop species, although the term may not be routinely applied by plant breeders. Cultivars in many perennial forage crops are regularly referred to as synthetic varieties.[3,11] In these species the broadest definition of the synthetic cultivar is generally adopted and parents are usually highly heterozygous, are typically not selected for combining ability, and are most often preserved for resynthesis as vegetative propagules. Natural intermating and successive generations of seed increase are important elements of the synthetic cultivar concept in these species because commercial quantities of seed may not be available until Syn-3 or Syn-4 generations.[3] Other than in these perennial forage species, synthetic cultivars are most common in maize, where parents are often inbred lines. Such synthetic cultivars are generally intended for use in environments where stability of performance may be paramount and the infrastructure necessary for the production of hybrid varieties does not exist.[12] Limited efforts have also been directed toward the development of synthetic cultivars in some partially self-pollinated crop species.[13]

CROSS-REFERENCES

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