Reverse Breeding Technology in Plant science

Saral Bhargav (Assistant Professor)

Dr. Sangeeta Lal (Assistant Professor)

Department of Botany , Mata Gujri Mahila Mahavidyalaya (Autonomous) , Jabalpur

Abstract

One of the most sought-after objectives in plant breeding is to directly produce parental lines for any heterozygous plant. Reverse breeding (RB) is a novel technique for achieving this goal. By means of meiosis engineering, RB produces homozygous parental lines that are perfectly complemented. The strategy relies on preventing meiotic crossing over in order to decrease genetic recombination in the chosen heterozygote. These plants produce male or female spores that, when cultured in vitro, contain combinations of non-recombinant parental chromosomes that result in homozygous doubled haploid plants (DHs). Complementary parents can be chosen from these DHs and used to recreate the heterozygote indefinitely. RB has the potential to drastically alter plant breeding in the future since traditional methods cannot fix heterozygous genotypes that are unknown. We cover a number of additional uses for RB in this review, such as breeding per chromosome.

Keywords : univalent segregation, spore regeneration, plant breeding, engineered meiosis, breeding per chromosome.

Introduction

The discovery that hybrid (F1) progeny often outgrow their homozygous parents in terms of size, growth traits, and yield—a phenomenon known as heterosis—was one of the most significant discoveries in plant breeding. Unfortunately, little is known about the potential variety of its underlying driving mechanisms (**Springer and Stupar, 2007; Stupar et al., 2008; Fernandez-Silva et al., 2009; Wei et al., 2009**). Breeders face significant challenges due to the unpredictable nature of heterosis: how can crop varieties be optimized for performance when the components necessary for success are unknown? By carefully combining unknown alleles and performing apriori selection on inbred lines, breeders can assess heterosis. The method's hit-or-miss quality makes it challenging to maximize heterosis's benefits. Here, we suggest an alternative approach based on the reversal of crop selection: the creation of well-defined populations with significant amounts of random variation and heterozygosity. Following an evaluation of these populations under various environmental factors (such as humidity, salinity, and latitude), the best-performing heterozygous germplasm is chosen for additional breeding.

REVERSE BREEDING

The two fundamental processes of reverse breeding are the regeneration of DHs from spores containing non-recombinant chromosomes and the suppression of crossover recombination in a chosen plant.. RB can also be used on plants with a known background in another application .In the event that crossing over is eliminated in the F1 hybrid as opposed to the F2 generation, chromosome substitution lines can be produced using RB. In the backdrop of the other parent, these lines have one or more chromosomes from one parent. Populations that segregate solely for the heterozygous chromosome(s) can be obtained by backcrossing the chromosome substitution lines to the original parental lines. Theoretically, chromosome rearrangement between two homozygous plants can occur in any way thanks to reverse breeding.

Uses of reverse breeding

1.Rebuilding heterozygous seed material

RB has the ability to expedite the development of varieties for crops in which a comprehensive collection of breeding lines is still absent. It is possible to propagate superior heterozygous plants in these crops without having any prior knowledge of their genetic makeup . It's astonishing how few DHs are actually needed. For example, only 98 DHs in maize ($x = 10$) are predicted to have a set of two reciprocal genotypes ($P = 99\%$).

2.Breeding based only on one chromosome

Numerous intriguing traits found in crops are derived from interactions between polygenic genes, which are frequently found on distinct chromosomes. Breeding on these quantitative traits is therefore challenging. When RB is applied to an F1 hybrid of known parents, chromosome substitution lines can be produced. These homozygous substitution lines for chromosomes offer new resources for the investigation of gene interactions. One chromosome can be homozygous in hybrids created when crossed with one of the original parents .however, hybrids with only one heterozygous chromosome can also be created The former makes it possible to investigate the epistatic relationships between background and genes that are involved. The basis of many intriguing traits in crops is polygenics. With the former, epistatic interactions between the background and genes that the substitution chromosome contributes can be studied. Plants with a single heterozygous chromosome will separate their progeny according to the traits found on that chromosome alone. Using recurrent backcrosses or selfing plants with a substituted chromosome, breeders can fine-tune interesting traits on a single chromosome scale. Better breeding lines with introgressed traits may result from this. The few instances provided here show that breeders have complete control over homo- or heterozygosity at the single chromosome level with RB.

3.CMS background backcrossing

Breeders use cytoplasmic male sterility (CMS) in a number of vegetable crops, including carrots and cabbages (**Chase, 2007**). The existence of male sterility in these systems poses a unique difficulty for RB. In these situations, DH plants can be produced by gynogenesis as opposed to androgenesis. The fact that the chromosomes from the maintainer line can be directly recovered in the cytoplasm of the sterile line in a single step makes this completely compatible with RB. Numerous crops, including Brassica, maize, sugar beet, cucumber, melon, rice, onion, sunflower, and barley, have been reported to exhibit gynogenesis (**Keller and Korzun, 1996**). However, when anther and microspore culture was introduced, the protocol's development or improvement for numerous species was frequently abandoned. However, once anther and microspore culture techniques were developed, the protocol's development or improvement for many species was frequently dropped. It is feasible to cross male sterile (A) lines with maintainer lines (B), which carry one copy of a restorer gene, in situations where the efficiency of gynogenesis is too low. It is possible to perform RB and the AB combination will be fertile. Restorer genes have been effectively inserted into rice (**Wang et al., 2006).** Therefore, it should be possible to perform RB in a "double suppressed" (CMS and crossover) background by using a restorer gene and a gene for crossover suppression in the same vector (both transgenes).

Conclusion

The regeneration of haploid spores into DHs after crossover suppression produces novel and effective breeding applications. The creation of complementary homozygous lines, which can be utilized to produce particular F1 hybrids, is one significant application. Furthermore, chromosome replacement lines that enable single-chromosome targeted breeding can be produced from F1 heterozygotes treated with RB. Commercial CMS lines that are widely used in contemporary agriculture are fully compatible with RB.

However, the method can only be applied to crops in which spores can regenerate into diploid hybrids (DHs) and in which the number of haploid chromosomes is 12 or less. There is also another reconstruction method based on omitting the second meiotic division, which results in unreduced second division restitution (SDR) spores; this method has been proposed for polyploids or species with high chromosome numbers. By using these SDR spores, it is possible to obtain chromosome substitution lines and achieve near reconstruction of desired phenotypes (Van Dun and Dirks, 2006).

REFRENCES

- Chase CD. Cytoplasmic male sterility: a window to the world of plant mitochondrial nuclear interactions. *Trends Genet.* 2007;23:81–90
- Couteau F, Belzile F, Horlow C, Grandjean O, Vezon D, Doutriaux M-P. Random chromosome segregation without meiotic arrest in both male and female meiocytes of a *dmc1* mutant of *Arabidopsis*. *Plant Cell.* 1999;11:1623–1634.
- Croser J, Lülsdorf M, Davies P, Clarke H, Bayliss K, Mallikarjuna N, Siddique K. Toward doubled haploid production in the Fabaceae: progress, constraints, and opportunities. *Crit. Rev. Plant Sci.* 2006;25:139–157.
- Fernandez-Silva I, Moreno E, Eduardo I, Arus P, Alvarez JM, Monforte AJ. On the genetic control of heterosis for fruit shape in melon (*Cucumis melo* L.) *J. Hered.* 2009;100:229–235.
- Keller ERJ, Korzun L. Ovary and ovule culture for haploid production. In: Jain SM, Sopory SK, Veilleux RE, editors. *In vitro Haploid Production in Higher Plants.* Dordrecht: Kluwer Acad Publ; 1996. pp. 217–235.
- Springer NM, Stupar RM. Allelic variation and heterosis in maize: how do two halves make more than a whole? *Genome Res.* 2007;17:264–275.
- Stupar R, Gardiner J, Oldre A, Haun W, Chandler V, Springer N. Gene expression analyses in maize inbreds and hybrids with varying levels of heterosis. *BMC Plant Biol.* 2008;8:33.

- Wang Z, Zou Y, Li X, Zhang Q, Chen L, Wu H, Su D, Chen Y, Guo J, Luo D, Long Y, Zhong Y, Liu Y-G. Cytoplasmic male sterility of rice with boro II cytoplasm is caused by a cytotoxic peptide and is restored by two related PPR motif genes via distinct modes of mRNA silencing. *Plant Cell.* 2006;18:676–687.