AgriCos e-Newsletter
ISSN: 2582-7049
Volume : 01 Issue : 04 August 2020 Article No: 51

Crop Heterosis Utilization

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SUMMARY

Heterosis is a natural phenomenon where by hybrid offspring of genetically diverse individuals display improved physical and functional characteristics relative to their parents. Heterosis has been increasingly applied in crop production for nearly a century, with the aim of developing more vigorous, higher yielding and better performing cultivars. three categories of crop heterosis utilization: intraspecific heterosis, intersubspecific heterosis and wide-hybridization heterosis.

INTRODUCTION

Heterosis is a natural phenomenon whereby hybrid off spring from genetically diverse individuals show increased vigor relative to their parents. Heterosis in crop species can be visualized in terms of increases in growth rate, total biomass, stress resistances, seed yield, and population fitness. The application of heterosis in crop breeding and production is the most important contribution of plant genetics to the development of agricultural technology in the last century.

What is Heterosis?

The phenomenon of heterosis was defined by Shull (1952) as "the interpretation of increased vigor, size, fruitfulness, speed of development, resistance to disease and to insect pests, or to climatic rigors of any kind manifested by crossbred organisms as compared with corresponding inbreds, as the specific results of unlikeness in the constitution of the uniting parental gametes." For our purposes, we will define heterosis as the difference between the hybrid and the mean of its two parents.

Specific characteristics of Heterosis

1.Heterosis is highly variable; the degree of heterosis varies with respect to the genetic distance of the parents, their reproductive mode, the traits investigated, the developmental stage of the and the environment.
2.It is largely universal and can increase crop yields by 15–50 % depending on crop type. The earliest utilization of heterosis was in maize (Zea mays), yield was increased by 15 % in hybrids relative to the superior open-pollinated varieties. By the late twentieth century hybrid maize accounted for 65 % of total maize cultivation and had contributed to a quadrupling of annual maize production
3.Increases in heterosis level diminish over time. On average, genetic gain for yield was gradually increasing by 1.5–2.0 % per year at the end of last century, albeit with a lessening of the heterotic increase Therefore, to maximize crop yields, breeders may focus on increasing heterosis level, improving the performance of inbred breeding lines, or both.

Classification of Crop Heterosis

Three categories of heterosis have been defined based on the genetic distance of parental lines.
1.Intraspecific heterosis
2.Intersubspecific heterosis
3.wide-hybridization heterosis

1.Intraspecific Heterosis

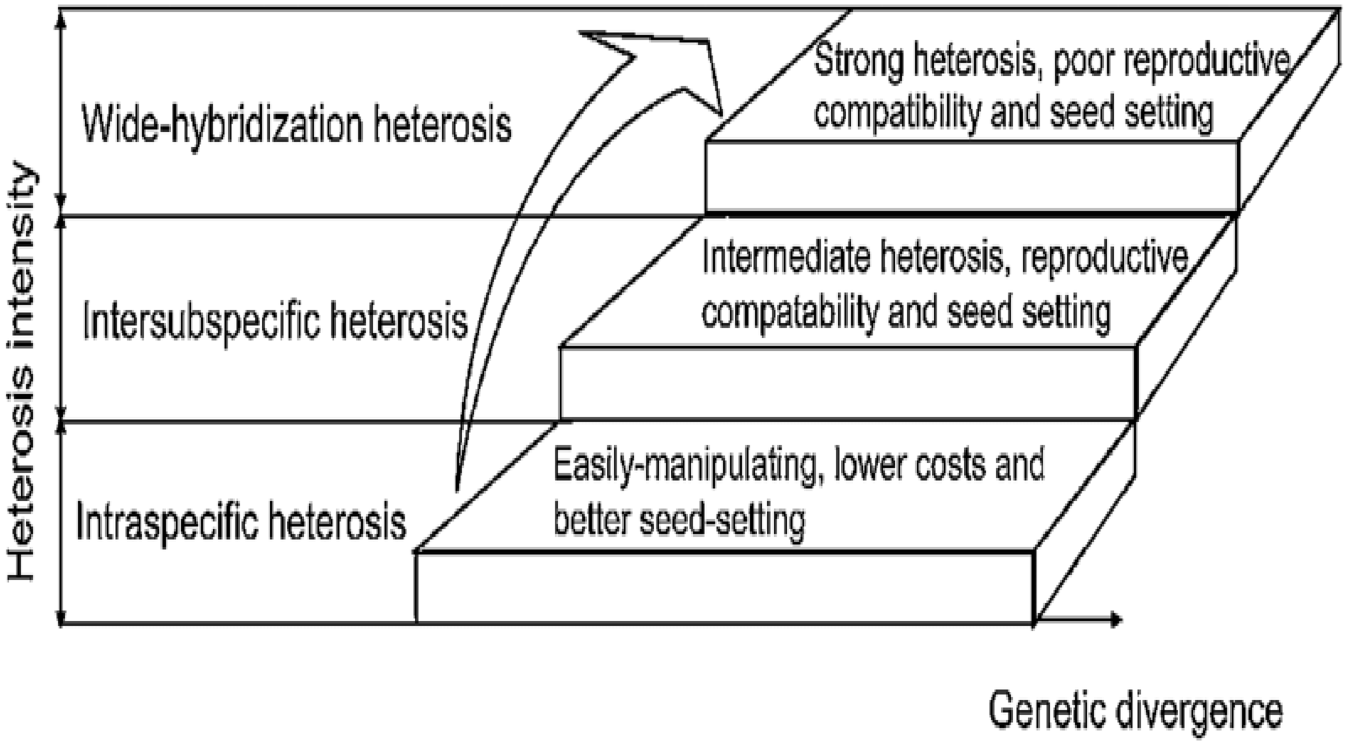
Crosses between two accessions belonging to the same species, Intraspecific heterosis favored choice of most breeders because it can be manipulated easily and results in lower breeding costs, higher breeding efficiency and better seed-set compared with wide-hybridization heterosis. To avoid the low levels of heterosis associated with crossing closely-related lines, crop breeders classify parental materials into heterotic groups based on molecular markers or physically testing combining ability.

2.Intersubspecific Heterosis

Crosses between two sub species, Intersubspecific hybrids display 8–15 % more heterotic potential than intraspecific hybrids, for example in rice *indica x japonica*. In intrasubspecific crosses show low and unstable seed setting and poor grain plumpness in the *indica x japonica* F1 has limited the practical application of these hybrids.

3.Wide Hybridization Heterosis

Crosses between two individuals of a different species or genus, for examples *Brassica oleracea* (cabbage/cauliflower) x *B. rapa* (Chinese cabbage), *Zea mays* (maize) x *Oryza sativa* (rice) and *Secale spp*. (e.g. rye) x *Triticum spp*. (e.g. wheat). With respect to wide hybridization, as long as geographical and reproductive isolation exists between species, strong hybrid vigor is observed, but similarly to intersubspecific crosses, poor seed setting and genetic instability often occur.



Classification and Characteristics of heterosis Utilization

Heterosis Utilization and Pollination-Control Systems

Superior cross combinations should have simple, low-cost, high yielding and stable seed production techniques. In order to control hybrid production in many species, floral castration methods are required, which can be classified into: (1) non-genetic castration, or, (2) biological pollination control technologies.

Non-genetic castration includes artificial castration and the use of chemical hybridising agents (CHA). Biological pollination control systems make use of cytoplasmic-encoded male sterility (CMS) (involving a cytoplasmic genetic male sterile line, a maintainer line and a restorer line), nuclear-encoded male sterility (NMS), self-incompatibility (SI), environment-sensitive genetic male sterility. The selection of pollination control technology is dependent on the species involved. A good pollination control system takes into consideration species-specific propagation methods, ploidy, flower size, flowering habits, manpower requirements, economic cost, mating type (hermaphrodite or dioecism), the presence or absence of genetic sterility (NMS, CMS and SI), the fertility and restoration ability of restorer lines, transformability, the degree of inbreeding depression (reduced vigor or yield due to inbreeding) and the sensitivity towards chemical hybridising agents.

Chemical hybridising agents are not restricted to particular species and do not require the laborious practise of transferring sterility and fertility genes from one species/line to another species/line, making it a promising alternative, these can enable breeders to develop hybrids with higher heterosis level in a shorter time.

Pollination control by artificial emasculation is mechanically intensive and difficult to apply in regions where the expense or limited availability of manpower is prohibitive.

Problems and Future Directions in Hybrid Breeding

1. Not every hybrid combination exhibits strong heterosis. This can occur when few heterotic loci, or low genetic diversity, exist in parent lines, emphasizing the need to select diverse lines enriched with heterotic loci.
2. Negative heterotic loci may occur simultaneously in the F1 generation and must be removed in subsequent generations without compromising the degree of positive heterosis.

CONCLUSION

The degree of heterosis tends to increase with increasing genetic diversity of the parents, this also increases the likelihood of meiosis abnormalities, such as poor chromosome pairing. Indeed, aberrant chromosomal rearrangements and transposon activations have been detected following wide hybridization. Hence, the divergence and stability of both parental and F1 genomes influence seed yield and the stable inheritance of agronomic traits.

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