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Exploitation of heterosis in rice for crop improvement

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Abstract
Heterosis or hybrid vigor is a natural phenomenon where by hybrid off spring of genetically diverse individuals show advanced physical and purposeful traits relatively to their parents and off spring. Heterosis has been increasingly implemented in crop developed for nearly a century, with the purpose of developing greater energetic, better yielding and better appeared cultivars. In this review present and examine three classes of crop heterosis usage: intraspecific heterosis, intersubspecific heterosis and wide-hybridization heterosis, with specific recognition on polyploidy species. Different pollination control systems used to reproduce for heterosis also are comparatively analyzed. Finally issues worried in heterosis studies and crop development are to be highlighted. In the present review the ultimate goal to provide insight into first class practices for amplifying heterosis ability.

Keywords: Heterosis, rice, wide hybridization, polyploidy, pollination control systems

Introduction
Heterosis has the following specific traits: firstly, heterosis highly variable, the degree of heterosis varies with respect to the genetic distance of the parents, their reproductive mode and the characters investigated (Zhou *et al*., 2012) [53], the developmental stage of the plants (Grosz-man *et al*., 2013) [14] and the environment. With respect to environmental transformation, biotic and abiotic conditions displayed to affect heterosis include soil type, topography, climate, solar energy, temperature and water availability (Munaro *et al*., 2011, Griffing and Zsiros1971, Langridge 1962 and Blum, 2013) [33, 13, 22, 2].
Secondly, heterosisis largely universal and can increase crop yields by 15-50% depending on crop type. Many of the major cereal crops as well as commercial varieties of vegetable and flower crops are popularly used hybrid seeds for increased agricultural performance (Duvick 1999, Birchler *et al*., 2003) [8. 9].
Exploitation of heterosis in rice is an important factor in crop improvement. It has been used to increase the yield and quality of rice production. Heterosis, or hybrid vigor, is a phenomenon that occurs when two different varieties of the same species are crossed. This results in the offspring being more vigorous than either parent variety. By exploiting this phenomenon, farmers can increase their yields and get better quality grains from their crops.
Exploiting heterosis in rice can also help to improve the nutritional value of the grains as well as reduce susceptibility to pests and diseases. With improved productivity and quality, farmers can get better returns for their efforts while also ensuring food security for their families and communities. Hybrid rice is grown broadly in Asian countries including China and India, where it is the staple cereal (Lamkey and Staub, 1998) [20]. In China, hybrid rice has a yield gain of 20-30 % over the best available inbred rice cultivars, facilitating a 44.1 % increase in production (Cheng *et al*., 2007) [6].
Thirdly, increases in heterosis level diminish over time. An average, genetic gain for yield was regularly increasing by 1.5-2.0 % per year at the end of last century, able it with lessening go the heterotic increase (Hoisington *et al*., 1999) [16].
The average yield gain in rice went from 3.1% per year in the1980s to 1.4% per year in the1990s and then 0.8%per year in the 2000s (Phillips, 2010) [39].
“The usual method for raising hybrids is to establish many inbred lines, make inter-cross and determine which hybrids are most productive in a given locality. (Davis and Rutger, 1976) [7] and (Virmani *et al*. 1981) [45] reviewed on heterosis in various agronomic traits of rice. Virmani *et al*., 1981) [45] reported a significant positive mid and high parent heterosis for yield ranging from 1.9 to 3.69% in rice. Standard heterosis for yield ranging from 16 to 63% was reported by (Rutger and Shinjyo, 1980) [40] and from 29 to 45% by (Yuan *et al*., 1994) [51].

Virmani *et al*., 1982) [44] reported 54 and 34% heterosis for better parent and standard heterosis, respectively. In China hybrid yield exceeded the best conventionally bred cultivars by 20 to 30% (Lin and Yuan, 1980) [25]. (Jennings, 1967) [18] found significant heterosis for vegetative growth to be negatively associated with yield in hybrids derived from tall parents. (Virmani *et al*., 1981, 1982) [45, 44] reported significant standard heterosis for both vegetative growth and grain yield."

Therefore, to maximize crop yields, breeders can also awareness on increasing heterosis level, enhancing the overall performance of inbred breeding lines, or each. Given the ability for heterotic profits, its miles crucial that we apprehend how first class to breed for heterosis. In this review, we classify heterosis into different classes in step with the genetic distance between parents. "We recommend distinct breeding techniques, based on these classes and on exceptional pollination control systems, to facilitate selection of the surest system for maximizing heterotic benefit."

Heterosis for yield and yield components

"Reviewed the literature published until 1978 on extent of heterosis for several agronomic traits and noted several reports showing significant heterosis and heterobeltiosis for yield, grains per panicle, grain weight, and panicles per plant in different crosses. The range of heterosis and heterobeltiosis observed for various agronomic traits." Values for heterobeltiosis and heterosis for a trial do not necessarily correspond to the same study; hence, some heterobeltiosis values for grain yield are higher than heterosis value. With few exceptions, the majority of these reports were based on 20 or less crosses which were perhaps made for pedigree breeding programs and did not necessarily involve selection of parents to manifest stronger heterobeltiosis. "Standard heterosis was not estimated in most of the studies because crosses were not made to develop F_1 rice hybrids (Virmani, *et al*., 1981) [45]. The above studies did not conform to the findings of Jennings (1967) [18] who observed heterosis only for vegetative characters (*viz*., leaf area index, light transmission ratio, tiller number, plant height, and dry weight) and not for reproductive traits, and thus concluded that heterosis in rice was not useful commercially."

It appear that hybrid vigour in yield had been because of notably high yield additives e.G., tiller number, panicle length, spikelet number, and thousand-grain weight. "Among the yield additives the highest heterosis effect changed into for panicle number accompanied with the aid of spikelet number, and panicle Length. Similar end result becomes mentioned by using (Mandal, 1982) [30]." There are many reports showing evidence of significant advantageous high determine heterosis and popular heterosis for yield and yield components (Carnahan, *et al*., 1972, Mohanty and Mohapatra, 1973, Saini and Kumar, 1973, Mallick, *et al.*, 1978, Virmani, *et al*., 1982, Luat, *et al*., 1985, Peng and Virmani, 1994) [3, 32, 44, 41, 29, 37, 51, 28]. Most crosses displaying sizeable trendy heterosis for yield were discovered to be owning heterosis for more than one commponents. Results received in China and IRRI indicate that heterotic F_1 combinations commonly display an elevated sink size thru an increase in spikelet per panicle, spikelet fertility percentage, and a thousand-grain weight (Virmani and Edwards, 1983) [46].

Classification and application of heterosis

"Three categories of heterosis have been defined based on the genetic distance of parental lines. These are: (1) intraspecific heterosis, resulting from crosses between two accessions belonging to the same species, (2) inter subspecific heterosis, resulting from crosses between two subspecies, and (3) wide-hybridization heterosis, resulting from crosses between two individuals of a different species or genus."

Intraspecific heterosis

Intraspecific heterosis is the popular desire of maximum of the breeders because it is able to be manipulated easily and results in lower breeding costs, better breeding efficiency and better seed-set (for seed-based totally crops) in comparison with wide-hybridization heterosis. "To keep away from the low levels of heterosis associated with crossing closely-related lines, crop breeders classify intra-species parental materials into heterotic groups primarily based on molecular markers or physically trying out combining ability. Each heterotic group fixes different alleles, which whilst blended with allele (s) from the opposite heterotic pool, can result in higher vigor." These positive interactions shape the base for the superior performance of the heterotic pattern (Schon et al., 2010) [42].

In rice, four heterotic patterns within two heterotic groups were identified in tropical hybrid rice from the International Rice Research Institute (IRRI) according to SSR markers and field trials (Xie *et al*., 2014) [48].

Intersubspecific heterosis

"Intersubspecific hybrids show 8-15 % more heterotic potential than intraspecific hybrids in rice (Li and Yuan, 2010; Peng *et al*., 2008) [24, 38]. "Rice has three subspecies: *indica*, *japonica* and *javanica*." Superior heterosis between *indica* and *japonica* has been observed in China and elsewhere, with 30-50 % higher heterotic gains than that provided by interva-rietal crosses. The *indica* and *japonica* subspecies of cultivated rice are genetically distant and each has excellent agronomic traits. The first generation (F_1) hybrid between *indica* and *japonica* rice exhibits later maturity, more luxuriance, larger spikes, more grains, higher tillering ability, a better root system, stronger stems, resistance to lodging, stronger regeneration, and higher biomass, than its parents (Gu, 2010, Wei *et al*., 2013) [15, 47]."

Despite the enhanced heterosis of many traits in inter subspecific crosses, it should also be noted that if the parents of intraspecific hybrids have higher adaptability or more favorable genes, intraspecific hybrids may surpass the heterotic potential of inter-subspecific hybrids. "Further more, discordance between parental genomes can lead to poor trait performance, for example with respect to seed setting and seed production, as a result of impaired pairing between homologous chromosomes during meiosis (Li and Yuan, 2010) [24]. Low and unstable seed setting and poor grain plumpness in the *indica japonica* F_1 has limited the practical application of these hybrids (Lapitan *et al*., 2009, Zhu and Liao 1990) [23, 54]. Though hybrid sterility is a major form of post zygotic reproductive isolation, it has been possible to find wide-compatibility genotypes that produce highly fertile hybrids when crossed to both *indica* and *japonica*." Assuchitis now possible to enhance *indica japonica* hybrid fertility by manipulating afew allelic interactions at a small number of wide-compatibility loci (Chen *et al*., 2011, Ikehashi and Araki, 1986) [4, 17].

The manipulation of wide-compatibility genes during hybrid rice breeding in China has resulted in normal seed setting rates in indica japonica hybrids (Wei *et al*., 2013) [47]. Now hybrids of indica and japonica show off strong vegetative vigor with a normal rate of seed setting and grain plumpness (Luan *et al*., 2007, Ouyang *et al*., 2010) [27, 36]. As such, more cultivars had been launched and implemented in breeding using javanica, or an intermediate type, as one parental line (Cheng *et al*., 2007, Zhong *et al*., 2005) [6, 52].
The indica-japonica hybrid system of rice might also act as a version for inter subspecific hybridization heterosis of different crops. Future investigations must try to find additional genes involved in hybrid sterility, clarify the underlying molecular mechanisms and make use of these findings to develop extra inter-subspecific hybrids to increase productiveness (Ouyang *et al*., 2009) [35].

Heterosis from wide hybridization
"Wide hybridization is described as a cross between two individuals at least species-level divergence. Examples encompass *Brassica oleracea (*cabbage/cauliflower) B. *Rapa* (Chinese cabbage), *B. Oleracea Raphanus sativus* (radish), *Zea mays* (maize) *Oryza sativa* (rice) and *Secale* spp. (e.g. Rye) *Triticum* spp. (e.g. Wheat). With recognize to wide hybridization, so long as geographical and reproductive isolation exists among species, strong hybrid power is found, however further to inter sub specific crosses, bad seed setting and genetic in stability regularly occur."

Uses of heterosis and pollination control systems
New, superior pass combinations should have easy, low-price, high yielding and stable seed production techniques. In order to manipulate hybrid production in lots of species, floral castration methods are required, which can be classified into: (1) non-genetic castra-tion, or, (2) biological pollination manipulate technologies. Non-genetic castration consists of artificial castration and the use of chemical hybridizing sellers (CHA). "Biological pollination control structures employ 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-touchy genetic male sterility, and F_2 residual heterosis." F_2 residual heterosis occurs while the yield of the F_2 generations in a few hybrids remains in all likelihood to be better than the control (Lamkey and Edwards, 1999) [21].
Genetic and metabolic engineering of such pollination control systems can also be carried out, which can also contain manipulation of CMS, nuclear-encoded pollination manipulate genes and inducible pollination control genes (Kempe and Gils, 2011, Engelke *et al*., 2011) [19, 10].
The selection of pollination manage era is depending on the species concerned. A desirable pollination control machine takes into consideration species-precise propagation methods, ploidy, flower size, flowering behavior, manpower necessities, economic cost, mating type (hermaphrodite or dioecism), the presence or absence of genetic sterility (NMS, CMS and SI), the fertility and restoration potential of restorer lines, transformability, the degree of inbreeding depression (reduced vigour or yield because of inbreeding) and the sensitivity in the direction of chemical hybridizing agents. "Generally, CMS is the preferred desire for pollination control and is taken into consideration first if the sterility and fertility genes are determined in associated species, since it happens naturally and has higher seed quality control." NMS also extensively takes place in nature and is the second one most popular pollination control system, as breeders can more without difficulty attain superior mixtures. "Environment-conditioned CMS and NMS are also widely carried out, but, because the call implies, the seed manufacturing and growth of environment-conditioned CMS or NMS strains are restricted with the aid of the local or seasonal surroundings." Environment-conditioned CMS and NMS thus also have a higher danger of producing sterile strains in F_1 hybrids than different types of pollination control systems.
"Chemical hybridizing agents are not restricted to particular species and do not require the laborious practice of transferring sterility and fertility genes from one species / line to another species / line, making it a promising alternative. Furthermore, these can enable breeders to develop hybrids with higher heterosis leveling a shorter time. Genetic engineering for pollination control also shows promise, particularly in new species, providing that these are amenable to genetic transformation and the regulation of genetically modified crops can be accepted." Pollination control by artificial emasculation is mechanically intensive and difficult to apply in regions where the expense or limited availability of manpower is prohibitive.

Heterosis response in rice
The utilization of population improvement methods in rice most effective became possible after the discovery of the male sterile line *via*: induced mutation of the rice. The initial breeding strategy to produce hybrids depended on 3 breeding lines known as A line (the male sterile line), B line (responsible to the genetic male sterility of the A line) and R line (used to maintain the fertility of the A line and to produce the hybrid seed). "The best system for these and different cross-pollinated crops would be the only-line approach using the apomixis system that allows maintaining the proper cultivar. Identification and assessment of male-sterile lines and their restorers, check move section to select heterosis combinatins and to provoke conversion of maintainer lines into male-sterile lines, back crosses to switch the cytoplasmic male-sterility to elite maintainer lines, trials to observe the combining ability (general and specific) of the parental lines and foundation seed production of all three lines." Production of breeding lines for the three- or -two line methods continues to be a difficult task for most of the rice breeding programs (Duvick, 1999) [8. 9].
Heterosis is the base of the great fulfillment in hybrid rice. "Currently, hybrid rice accounts for 55% of the whole planting acreage of paddy rice in Far East Asia and the yearly increased rice production due to planting hybrid rice quantities to twenty million metric tons, which could provide prime staple meals for 70 million people (Lu, *et al*., 2002) [26]." Hybrid rice varieties have a yield advantage of 10-20% over the best conventional inbred varieties using similar cultivation conditions (Lu, *et al*., 2002) [26]. "In rice breeding, most agronomic and grain quality traits are controlled by many genes each of, which has a relatively small effect on the overall phenotype. These traits do not show discrete phenotypes, consequently they are often measured and given a quantitative value and are referred to as quantitative traits. Quantitative traits are difficult to study because the phenotypes do not give an insight into the genotype. The

expression of genes controlling quantitative traits can be greatly influenced by the environment. Consequently, the improvement of polygenic traits by traditional breeding methods is time consuming and the gains are harder to realize." Breeders usually overcome this problem by multi environmental evaluation of replicated trials to capture the effect of the environment.

Due to the intractable problem encountered whilst looking to enhance quantitative characters by using conventional manner, breeders and geneticists have considered the potential use of DNA markers to identify chromosomal regions harboring genes that affect the quantitative characters. Morphological markers have been the primary era of markers for use for identity and choice for quantitative traits loci. "Very sluggish progress become made inside the use of these markers due to the undesirable results of many of the markers on the target phenotype. The impact of the marker genes on the quantitative tendencies became often larger than that of the connected Quantitative Trait Loci (QTL), hence it changed into hard to efficaciously and considerably use those markers to look at quantitatively inherited tendencies (Tanksley and Nelson, 1996) [43]. Moreover, there was a dearth of available segregating genetic markers (Duvick, 1999) [8, 9]." Several efforts had been made to introgress useful genes into elite rice types through interspecific hybridization with varying amount of success. Recent destroy throughs in every other subculture and molecular biology provide extra opportunities for rice breeders to increase a brand new generations of rice varieties which might be better adapted and high yielding. It is now feasible to pick out for molecular markers connected to traits of interest (marker assisted choice) as opposed to deciding on for the developments themselves. Chromosomal regions controlling various agronomic traits had been identified in rice. The QTL had been found out thru their association with molecular markers and through the year 2000, greater than one thousand QTL had been documented in rice (Xu et al., 2004) [49]. However, using these QTLs with the aid of breeding programmes continues to be in its infancy. Only some of the stated QTLs were used for crop development.

Problems and future directions in hybrid breeding

Some problems remain in hybrid breeding. Firstly, not every hybrid combinations exhibits strong heterosis.

This can occur while few heterotic loci, or low genetic diversity, exist in parent lines, emphasizing the need to choose numerous line enriched with heterotic loci. Additionally, negative heterotic loci may also occur concurrently inside the F1generation and ought to be eliminated in next generations with outcome promising the degree of tremendous heterosis. Furthermore, as mentioned, even though the degree of heterosis stands to growth with growing genetic diversity of the parents, this also increases the chance of meiosis abnormalities, including poor chromosome pairing. Indeed, aberrant chromosomal rearrangements and transposing activations had been detected following wide hybridization (Chen and Ni, 2006, Nicolas et al., 2007) [5, 34]. Hence, the divergence and stability of both parental and F1 genomes impact seed yield and the stable inheritance of agronomic traits.

In mild of the present day troubles in our ability to utilize heterotic potential, there stays a want to: (1) identified and manipulate additional wide-compatibility genes to assist stable genome compatibility among distance species. (2) identify and functionally represent positive heterotic loci. (3) pyramid wide-compatibility genes and positive heterotic loci right into a common genetic background. (4) Deepen our under-status of the mechanisms involved in genomic structural in stability within the F1, and (5) develop high efficient pollination control technology on a species-specific basis.

Conclusion

Exploitation of heterosis in rice crops provides enhancing food security and represents a greatest applied achievement in the discipline of plant breeding programmes. The more diverse of the parents the higher in the heterosis on their offspring. Breeders can also awareness on increasing heterosis level, enhancing the overall performance of inbred breeding lines, or each. Given the ability for heterosis profits, its miles crucial that we apprehend how first class to breed for heterosis. In this review, we classify heterosis into different classes in step with the genetic distance between parents. We recommend distinct breeding techniques, based on these classes and on exceptional pollination control systems, to facilitate selection of the surest system for maximizing heterosis benefit. We goal to provide insight into first class practices amplifying heterosis ability. Hybrid cultivars have been adapted hastily in view that their advent with the aid of occupying 100% of production area Hybrid rice varieties have a yield benefit of 15-20% over the pleasant traditional inbred varieties using comparable cultivation situations. Hybrid cultivars had been followed hastily on the grounds that their creation by using occupying a 100 % of production area

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