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Review on hybrid seed production of wheat: Problems and prospective

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Abstract
The number one aim of any plant breeder is to enhance crop genotypes. The improvement of advanced hybrids is one of the only techniques for this purpose. The many cereal vegetation, which includes maize and rice, have benefited from heterosis breeding. Hybrid improvement is a feasible alternative for breaking yield plateaus in self-pollinated vegetation inclusive of wheat. A gadget which can manipulate self-pollination is needed for any powerful hybridization programmed. Wheat is a extraordinarily self-pollinated crop, and quite a few techniques for controlling selfing had been attempted to make the most heterosis on this crop, which includes hand emasculation, male sterilization structures, and chemical hybridizing agents. However, every of those structures have its very own set of advantages and drawbacks. We tried to cowl all elements of hybrid wheat breeding on this review.

Keywords: Wheat, hybrid, CMS, CHAs

Introduction
Food is the basic need of every human being. Cereals are the world's most widespread staple food. Of all grains, wheat (*Triticum* spp.) is one of the most important staple foods in human nutrition. Wheat (*Triticum* sp.) is an annual cereal that is grown worldwide and is used as a staple food in almost every country on earth. It is commonly referred to as the "king of grains," which illustrates the importance of this culture. Currently, 749.46 million tons of wheat are produced worldwide (FAOSTAT, 2016) [5]. However, due to the growing population, the demand for wheat is expected to increase in the near future. With the same population growth, the world population will be around 9 billion in 2045, around 35% more than today's population (Bavel, 2013) [1]. To feed such a large population we need to increase total wheat production, which can be done in two ways; either by increasing the area under wheat or by improving production per unit area. Since the area is limited, and with the increase in population, the total area of the cultivation of wheat will be reduced, we should focus on the second option. India's focus at the moment is on the development of hybrid wheat for favorable environments in the north western plains of the Ganges in hopes of higher yields.
Some private companies, such as Syngenta, are also making investments in the development of hybrid wheat varieties or the key peripheral and wheat-growing areas. Wheat productivity has increased since the 1960s due to the development of improved dwarf wheat and management practices. But this improvement is in recent years because there is now a problem of lack of genetic variability in wheat. Breeders have already exploited most of the useful genetic variability in wheat, as a yield platue has been achieved (Ray *et al*., 2013) [19]. In such a situation, heterosis breeding can be an alternative to solve this problem. Freeman (1919) [6] was the first scientist who succeeded in developing a wheat hybrid. As a result, many scientists reported significant heterosis in wheat (Singh 2010; Longin *et al*., 2013) [20, 13]. Mühleisen's problem in developing wheat hybrids is that it is a highly self-pollinating plant. In order to develop a hybrid we need to castrate the wheat flowers, which is not possible for commercial hybrid seed production. This review focuses on different approaches that can be used to develop hybrids in wheat and the problems involved.

Conventional Method
Wheat is a bisexual plant and, due to its cleistogamous nature, is very self-sufficient (Chelak 1989) [3]. The traditional method of hybrid production requires manual emasculation, or the removal of anthers. For emasculation, plants must be selected at an appropriate stage. Wheat

starts flower maturation in the middle and progresses both up and down. The plant that we want to use as a female is selected and castrated when its spike just comes out of the flag leaf i.e. in the starting phase. Spikelets above and below ripen late, so they are removed. From the remaining spikelets, the middle florets are removed first to create enough space for easy emasculation. Within a floret, the glumes are shortened by 2/3 with scissors and the three anthers removed with pointed forceps without touching the stigma (Wells and Caffey, 1956) [22]. The emasculated spikes are bagged to avoid contamination with foreign pollen. In the morning of the next day, the spike of the pollen parents is removed and the spikelets are shortened in the same way as described above. After five minutes of sun exposure, the emasculated females are sprinkled with it. The process of manual emasculation and pollination is a very laborious and slow process. It is only applicable to plant species that have large flowers and multiple ovules per flower. But with wheat, the success rate using this method is very low. An alternative method uses hot water (40-45 °C) to castrate females (Mukasa *et al*., 2007) [16]. However, this method cannot be carried out under field conditions either. These traditional methods are not suitable for hybrid development in wheat due to their lengthy and labor-intensive nature. Seed formation is also a major concern when using the emasculation technique. Experiments can be done, but hybrid development does not use them economically.

Using Male Sterility

In any crop, hybrid development becomes easy when the female parent behaves like a male-sterile plant. Under such conditions, the laborious process of emasculation is bypassed. This is primarily achieved through one of the following approaches:

1) Cytoplasmic/genetic male sterility (including YA-type CMS);
2) Artificial induction via chemical hybridizing agent (CHA) or photoperiod/temperature treatment;
3) Genetic male sterility;
4) Chromosomal sterility. In wheat plant, many systems have been tried like cytoplasmic male sterility, hybridizing agent etc.

Genetic male sterility

Male sterility can be controlled by genes present in the nucleus or cytoplasm. In the male infertility genetic system, the core genes that control male fertility are mutated. A large number of male-sterile mutants have been identified in wheat, including Ms2, Ms3, Ms4 that are dominant while ms1a, ms1b, ms1c, ms1d, ms1e, ms1f and ms1g are recessive in nature (Singh *et al*., 2010) [20]. Of these, ms1a and ms1b are the result of a deletion on the short arm of chromosome 4B due to ionization with radiation while the rest are spontaneous random mutations (Singh *et al*., 2010) [20]. Genetic male sterility caused by recessive alleles is useful because it can be maintained by the dominant counterpart, but only half of the offspring from it are sterile (Hermsen, 1965) [17]. The remaining 50 percent of plants that are male fertile must be removed in cross blocks prior to flowering, making this system uneconomical and unreliable as even if a single fertile plant remains, it will create a problem of hybrid segregation. Distinguishing between sterile and fertile plants can be made at an early stage when sterility is found to be related to a specific morphological or molecular marker.

Cytoplasmic-Genetic male sterility

The second kind of male infertility is caused by cytoplasmic genes, specifically due to a defect in mitochondrial genes (Chase, 2007) [2]. it is called cytoplasmic-genetic male sterility as restoration genes (fms1 and fms2) in the cell nucleus is needed for sterile plant restoration (Li *et al*., 2006) [12]. CMS is the result of a defect in the mitochondrial gene. This type of sterility was first found in wheat lines co-developed by substitution of wheat cytoplasm that of A. caudate (Kihara, 1951) [11]. In wheat, various CMS sources are available in related species. The most common of these is CMST, identified from *Triticum timopheevii* (Wilson and Ross, 1962) [23]. This system includes three lines for a successful hybrid development program i.e. cytoplasmic male-sterility line (line A), a maintainer line (line B), and a restorer line (line R). A three-line hybrid wheat seed production program consists of the following three lines: (1) Line A, the female parent, who must be male sterile; (2) R-line, the male parent, carrying one or more fertility-restoring (Rf) genes; and (3) Line B, the maintainer line that is fertile but genetically similar to the CMS female (Aline). Line age B is isogenic to lineage A because the genetic makeup of linesages A and B is the same, except that lineage B has fertile cytoplasm. When lines A and B are grown in isolation, the seed developed in line A is of the sterile type and the seed developed in line B is from the maintainer line. The third lineage is the R lineage, which has a dominant core gene for fertility restoration from the A lineage. When line A is pollinated with pollen from line R, fertile hybrid offspring are produced. However, this system again has some limitations, including a tedious process of maintaining three lines (lines A, B, and R), incomplete or partial recovery of fertility, sterility breakdown, and unwanted side effects of foreign cytoplasm (Singh *et al*., 2010) [20]. The *T. timopheevii* CMS system for hybrid seed production is considered to be the best among the available CMS systems. Therefore, it was used on a larger scale in for the production of hybrid wheat and hybrid triticale (Mukai and Tsunewaki 1979; Adugna *et al*. 2004; Singh *et al*. 2010; Würschum *et al*. 2017a, b) [20]. But restoration of fertility in lines carrying Timopheevii cytoplasm was often partial, so pyramiding of two or more Rf-genes in the same male parent was considered a necessity Because of these limitations, the CMS system is rarely used in wheat breeding.

Using XYZ System

Driscoll (1972) [4] developed this system using male sterile wheat mutants and foreign chromosomes from Rye (*Secale Cereal* L. Cornerstone). In this system, the male sterile lines (Z lines) have all of the wheat chromosomes except for a small deletion in 5B (Cornerstone mutant). A line (Y-line) with a foreign chromosome (5R with Ms) from rye is used to maintain this lineage. The Ms gene is linked to a dominant m-marker, the Hairy Stem (Hp), and produces two types of pollen: i.ms and msMsHp, while the Z lineage eggs contain only ms-type gametes. When line Z is cross-pollinated with line Y, ms/ms MsHp and ms/ms progeny are produced. Since fertile plants do not have such hairy stems, they can be easily removed. The male parent used for fertility restoration and hybrid development develops by adding the 5R chromosome set from rye (Driscoll 1972) [4]. This system is somewhat useful, but the marker gene is not expressed until later in the plant's life.

Chemical hybridizing agents (CHA)

As is well known, the following four two-line systems are available to induce male-sterility for the purpose of hybrid seed production, although not all of them have been used in wheat: (1) chemical hybridizing agent (CHA) induced male-sterility; (2) photoperiod-sensitive cytoplasmic male sterility (PCMS); (3) recessive thermosensitive male sterility (TGMS); (4) Photoperiod and temperature-sensitive male sterility of the gene (PTGMS). A brief overview of each of these systems can be found here. In self-pollinated crops such as wheat, where out crossing is very rare, the transmission of genetic or cytoplasmic-genetic male sterility is a very difficult task, since regular backcrossing is required for the transmission of these systems. This problem can be overcome through the use of various chemicals, commonly known as chemical hybridizing agents (CHAs), which disrupt the development of male gametes without affecting the female reproductive tract (McRae, 1985) [14]. If these chemicals are sprayed on a line at a certain stage, no pollen will be formed and therefore the line will behave like a female line. A large number of chemicals have been tested on wheat for hybrid development, including maleic hydrazide, DPX 3778 and Ethrel (Hoagland *et al*., 1953) [8]. Using CHA, several commercially viable hybrid wheat cultivars were developed and approved for commercial cultivation in the 1990s and later. Domino' was published in the US by Hybri Tech Monsanto and 'Hpo-Precia' was released in france. These CHAs are called first generation CHAs and there are controversial results for most of these CHAs (Parodi and Gaju, 2009) [17]. Effects on treated plants and their progeny have broad applicability, are effective in a wide variety of plant stages and environments, and should not be carcinogenic are some requirements to be met (Pickett, 1993) [18]. But none of the chemicals tested to date meet all of these requirements.

Future Prospectus

With hybrid development being the only hope of maintaining productivity to feed the growing population, concerns about hybrid development in wheat are growing. However, large-scale production of hybrid wheat requires a reliable wheat fertility control system. A shared gene system has been developed in wheat using modern transgenic techniques. In wheat, male sterility was induced using the barnase gene (Kempe *et al*., 2014) [10]. Barnase barstar system for the production of hybrid seed has already been used by Bayer Crop Science for the production of canola, (Whitford *et al.* 2013). As is well known, the barnase barstar system uses two dedicated genes, the barnase gene, which encodes a ribonuclease, and the barstar gene, which encodes a ribonuclease inhibitor (first discovered in Bacillus amyloliquefaciens) to be expressed only in the anther mat in a tissue-specific manner. In the female parent, the barnase gene is expressed in the tapetum and interferes with pollen development, causing male sterility. The male parent carries the gene encoding barstar, which is expressed in F1 hybrid plants and inhibits barstar activity, thereby achieving full seed set in F1 plants (Mariani *et al*. 1990, 1992). The male-sterile line is maintained by backcrossing with a non-transgenic line. The backcross would produce a seed mix from which 50% of the seed would produce male sterile plants. Although this process has been used successfully for hybrid canola production, its commercial utility in other crops, including wheat, has yet to be realized. But in developing countries like India, the use of transgenics faces several criticism. Therefore, in order to save the future generation from broad-spectrum hunger, it is necessary to work quickly in this field.

Conclusion

Indian wheat scientists have made tremendous efforts over the past 40 years to achieve food self-sufficiency and promote the accumulation of buffer stocks in the country. In order to keep up with the growing population and the changing eating habits of rural and urban people, it is necessary to increase productivity levels. Various plant breeding tools are becoming more important in the changing scenario for the further advancement of wheat; one of them is the development of hybrids. The main requirement of hybrid development in any crop is the presence of the degree of heterosis. This offers the possibility for a hybrid development. Because wheat is a strictly self-pollinating plant, finding parents that have desirable traits to enhance out crossing is crucial, and traits such as anther length, anther extrusion, and pollen viability in male parents, and stigma length and opening of flowers in female parents are of great importance. In addition, male sterility is required as well as an effective fertility restoration system to reduce the cost of hybrid seed production. Suitable CMS lines with high-yielding backgrounds are required for this, which can be achieved by diversifying the available timopheevi-based CMS lines.

To attain extra fulfilment with inside the vicinity of hybrid wheat, a number of the sub sequent regions want attention.

(1) Enhancement of seed manufacturing efficiency to make wheat seed business appealing and sustainable. Exploration and beneficial usage of phonology and reproductive biology (anther extrusion, quantity of pollen manufacturing, prolonged pollen viability, elevated female receptivity, etc.) might also additionally allow better seed set in female-sterile figure with inside the manufacturing block main to decreased fee of hybrid seed.

(2) The volume of heterosis in wheat (i.e. 15–25% over mid-figure, and 10–15% over business figure) is corresponding to heterosis achieved in maize at some point of early years (1920s–1940s) of hybrid maize breeding. These can be advanced in future for growing high-yielding wheat hybrids via expertise of the numerous practical haplotypes and their association with heterosis and through improvement of heterotic groups.

(3) Genomics-based prediction of single-go overall performance can boom the genetic profits in line with unit time.

(4) Speed breeding might also assist in rapid improvement of parental traces through backcrossing mixed with molecular marker-based choice for key developments consisting of fertility recuperation and stronger cross-pollination.

(5) Replacement of CHA through CMS/chms or a transgenic machine for discount of seed manufacturing fee to permit screening of many testcrosses in many different environments.

(6) Technologies like split-gene and genome enhancing might also offer appealing GMO/non-GMO solutions to the issues like oligogenic (in place of monogenic) fertility recuperation.

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