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Breeding strategies for hybrid rice parental line improvement

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ABSTRACT

In our country, significant progress has been made in the development of hybrid rice parental lines both female and male parents with good floral traits. An array of hybrids with good grain quality (both unique Basmati type and medium slender (MS) grain type) is developed. Efforts are focussed on the development of restorer lines through exploitation of inter sub-specific hybridization, recurrent selection and population improvement that will help in the development of highly heterotic rice hybrids. The female parental lines are being improved for traits like stigma exsertion and high outcrossing that helps in higher seed yields, thereby reducing the hybrid seed cost. Efforts are on to develop appropriate parental lines that can help in the development of suitable hybrids in late duration group and also for unfavourable ecologies. Many newly developed parental lines are being fortified with resistance genes for major diseases such as BB, blast and insect pests such as BPH that will help in the development of hybrids having resistance to major pests and diseases.

Key words: *Hybrid rice,CMS line, maintainer, restorer lines, gene pools*

INTRODUCTION

Hybrid rice is a proven and viable technology to enhance the rice production and productivity and it was launched in India in 1989, after its successful adaptation In China. As a result of intensive research efforts over the last three decades, a total of 97 rice hybrids were released for commercial cultivation in different rice growing regions of the country. The area planted to hybrid rice in the country during *Kharif* 2017 was around 3m.ha. (5% of the total rice area of 44 m.ha) and has contributed 3-4 m.t. of additional rice to the total rice production in the country.

However, its adoption is rather slow than the expected level. The main reasons for this are marginal heterosis, narrow genetic base of the parental lines, high seed cost because of seed production issues, non-availability of hybrids in medium late/late duration groups besides quality concerns. All these concerns can be addressed through focussed parental line improvement by developing an array of appropriate genotypes that can help in the development of hybrids with enhanced yield heterosis, better grain quality and resistance to major biotic stresses. In this paper, different approaches and strategies for parental lines improvement is presented.

Diversification of CMS sources

All the hybrids released in the country are based on a single source of cytoplasmic male sterility (CMS) *viz.,* Wild Abortive (WA) system. Dependence on a single CMS source on a long run may result in genetic vulnerability of hybrids to sudden outbreak of diseases and insect pests. Hence, it is required to develop CMS lines with diverse cyto-sterility sources. Wild species of rice such as *Oryza nivara*, *Oryza rufipogon* and *Oryza perennis* were already found to have alternate cyto-sterility sources, but their commercial exploitation was limited by the fact that no good restorers are available for these CMS sources like WA system. Intensive efforts are being made to identify suitable restorers for these various sterility sources. Another sterility source Kalinga I and a CMS line CRMS 32A is developed using this source and a hybrid *viz.,* Rajlaxmi has also been developed from this new source (NRRI, Cuttack).

The People's Republic of China (where the hybrid rice technology is originated) has succeeded in diversifying the CMS sources. Though CMS WA-type remains the dominant type in three line hybrid rice production, they could able to reduce the dependency on this system from 69% in 1996 to 47% in 2003. Among the other types of CMS, CMS-ID has been used widely in recent years because of its good flowering habits and grain quality. Its proportion has increased from less than 10% in 1996 to more than 20% in recent years (Shi-hua et al., 2009). Another CMS system viz., CMS-G&D has also been successfully deployed in the development of hybrids in China (Shi-hua et al., 2004).

Improvement of CMS & Maintainer Lines

One of the major limitations of the hybrid rice technology is the higher seed cost and it's acting as deterrent in wide spread adoption of hybrid rice cultivation in the country. This can be overcome by developing CMS and maintainer lines with good floral traits such as high outcrossing ability etc. To achieve this, single, double and multiple crosses among maintainers and outstanding partial maintainers (having desirable traits) may be used to develop large segregating generations. The population size in F_2 should be sufficiently large (> 2000-3000 plants) and careful selection has to be exercised for outcrossing and combining ability related traits by retaining sufficient genetic diversity of the segregants. Selection for plant type, grain type, stigma exertion (Takano Kai et al., 2011), elongated uppermost internode (Singh et al., 2007) and other easily observable traits can be made in early segregating generations and combining ability of the desirable fixed lines will be tested at F_5/F_6 stage after confirming the presence of stable maintainer genes, through test crossing.

Two promising maintainer lines v*iz.,* APMS 6B, IR 68897B were improved for stigma exsertion trait through back cross breeding approach with donor genotypes *viz.,* BF 16B and BF 2096 (Singh et al., 2015). Another popular maintainer line IR 58025B has been improved for elongated uppermost interned-eui (Rahul et al., 2016).

It's essential to improve the maintainer lines for major biotic stresses, so that the same can be incorporated in CMS lines, which will help in the development of hybrids with resistance to major biotic stresses. IR 58025B has been fortified with bacterial blight (BB) and blast resistance genes through marker-assisted backcross breeding strategy (Hari et al., 2013). By adopting the similar strategy, two more maintainer lines *viz.,* Pusa 6B for BB resistance (Basavaraj et al., 2009); DRR 17B for BB, blast, gall midge resistance (Balachiranjeevi et al., 2015) have been improved. Promising maintainers like these, are being converted into new/improved CMS lines through recurrent back crossing.

Improvement of Restorer Lines

To increase the yield heterosis of the rice hybrids from the present 15-20% level to at least 25-30%, it's essential to focus on the restorer line improvement by adopting different recombination breeding strategies *viz.,* pedigree, backcross, incomplete backcross, single seed decent, modified backcross methods, multiple convergent improvement, genetic male sterility facilitated recurrent selection methods.

Choice of parents depends on the objective of the breeding program. Genetically diverse donors for various traits like better plant type (tropical japonica parents possessing wide compatibility genes), better restoration ability, high pollen production, relatively tall stature, better grain quality as per the local requirements, multiple disease and insect pest resistance, good GCA and SCA etc. should be used in the crossing programme. Single, three way and multiple crosses among restorers and partial restorers may be used to develop large segregating generations. Depending on the purpose the type of crosses may be R_1 x R_2, R_1 x(R_2 x R_3), R_1 x PR, R_1 x (PR x R_2), R_1 x (PR_1 x PR_2), PR x (R_1 x R_2), PR_1 x (R_1 x PR_2), (R_1 x R_2) x (R_3 x R_4), (R_1 x PR_1) x (R_2 x PR_2) and so on.

It's essential to improve the restorer lines for major biotic stresses, so that hybrids with resistance can be developed. The popular restorer lines *viz.,* KMR 3 (Hari et al., 2011); PRR 78 (Basavaraj et al., 2010, Lalitha Devi et al., 2013) for BB resistance; PRR 78 for blast resistance (Vikas et al., 2012); RPHR 1005 for BB and blast resistance (Abhilash Kumar et al., 2016) have been improved through marker-assisted backcross breeding strategy. Efforts are on to improve few more restorer lines *viz.,* BCW 56, EPLT 109, DR 714-1-2R, in a similar way.

Genetic male sterility (GMS) facilitated population improvement is carried out for improvement of restorer lines. As against quick fixation of genes during selfing generations of recombination breeding, genetic male sterility facilitated recurrent selections provide opportunities for continuous recombination, accumulation of favorable genes, broadening of the genetic base and breaking of undesirable linkages. By combining this strategy with Marker Assisted Selection (MAS), efforts are on develop a new set of restorer lines having resistance to multiple biotic stresses.

Inter sub-specific (*indica* x tropical *japonica*) hybridization approach, will help in developing parental lines that can be utilized in identification of hybrids with enhanced yield heterosis. However, a major difficulty encountered in the development of such inter-sub specific hybrids is the partial hybrid sterility (HS) frequently observed in most indica/japonica crosses. A special class of rice germplasm, known as wide compatible varieties (WCVs), can produce hybrids with normal fertility when crossed with both *indica* and *japonica*. Out of several genes reported to be involved in hybrid sterility, the S5 locus on chromosome 6 is considered to be the major. Sundaram et al., (2010) developed a functional marker which can distinguish all the three alleleic states (*i.e., indica*, *japonica* and neutral at S_5; this marker is being effectively used in hybrid rice breeding programme to identify the lines having S_5 neutral allels (Revathi et al., 2010).

Certain popular varieties of our country like Swarna, Samba Mahsuri, which are considered as mega varieties occupying substantial area under cultivation across the country and it's desirable if we develop hybrids similar to these mega varieties. However, these varieties can't be used in the hybrid breeding programme for the reason that they are found to be partial restorers. In order to use these genotypes, efforts are being made to convert them into usable restorer lines, by crossing them with popular restorer lines *viz.,* KMR-3, IBL-57 and trying to identify the promising restorers in the advance segregating generations. A set of restorer lines are developed and identified, following this strategy and they are being utilized in the development of new hybrid combinations.

Wild species of rice are also being used in the improvement of restorer lines. Of the two major effect yield enhancing QTLs *yld2.1* and *yld8.2* mapped from an Indian accession of *Oryza rufipogon*, *yld2.1* was introgressed into KMR 3, a restorer line of popular hybrid KRH 2 and several introgression lines of KMR 3 with upto 20% yield increase have been obtained (Sudhakar et al., 2012) and these restorers are being used in the development of new hybrids.

Development of heterotic gene pools

A concept, well exploited in corn in development of gene pools that led to development of highly heterotic hybrids, needs to be exploited in the improvement of hybrid rice parental lines. The work has been initiated in this direction by pooling restorer as well as maintainer lines and to study the extent of diversity among the lines and after classification in to different groups, selected lines from each group will be intermated with other lines from each group and also with lines from other groups to estimate their combining ability and heterosis. Our aim is to develop initially gene pools in different duration groups following this strategy.

All these strategies will hopefully lead to the development of better parental lines and hybrids, helping in the expansion of hybrid rice area and increased production and productivity in the country.

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