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Frontiers in Rice Breeding

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Abstract: History of rice breeding is very old and runs back to 60 years. Initial efforts were to purify land varieties followed by hybridization and selection. Later green revolution progressed and then followed the era of hybrids. Chinese developed many hybrids with outstanding yield performance. New endeavours following this are molecular breeding, and transgenic. Molecular techniques are another promising technique implemented in rice breeding. The time that had been spent earlier for the selection of progenies and parents with desired gene(s) got reduced a lot with the identification of gene tagged markers. Use of markers for the identification of genotype is termed as marker assisted breeding. To get a faster and accurate desired development, transgenic came in to picture.
Keywords: hybrids , yield performance, transgenic,

INTRODUCTION

Rice, the world's most important food crop, is one of the crops responsible for the miraculous changes in the agriculture during1960s and 1970s through green revolution. Various ongoing rice breeding programs in all different regions around the world indicates the importance given to this crop species by scientists. In addition to that, this crop has three Consultative Groups on International Agricultural Research (CGIAR) centers: the International Rice Research Institute (IRRI), with global directive; the West Africa Rice Development Association (WARDA), with directive to work in West Africa; and the International Centre for Tropical Agriculture (CIAT), with the regional directive for Latin America [1].

The improvement of modern semi – dwarf rice varieties has changed rice cultivation in tropical, subtropical and temperate Asia. The two rice varieties that imply a major event in rice research in Asia and predominantly for India are Taichung Native – 1, resulted from the cross of Dee - Geo - Woo - Gen and Tsai - Yuan - Chung made in 1949 by breeders at Taiwan and IR-8.A foundation of the 'Green Revolution' was the new varieties of cereal crops developed through the exertions of Norman Borlaug, the father of the Green Revolution during 1960's. One among them is IR8 rice, known as "miracle rice," developed at the International Rice Research Institute (IRRI) [2].

The development of technologies and inventions removed major problems that we were facing by the use of conventional methods in rice breeding. In the last few decades, rice yield has undergone two big dives, one, as the result of genetic improvement: using semi dwarf gene plant height has been reduced and harvest index was increased. Second one is the utilization of heteros is by producing hybrids. Consequently, rice yield has been doubled and tripled in most parts of the world within a period of thirty years from 1960s to 1990s [3].

In this context, some of major new techniques have been discussed hereunder three headings – Hybrid technology, Marker assisted selection and Genetic engineering which became the frontiers of rice breeding that paved path for several rice varieties in the course of time.

I. HYBRID RICE

Heterosis, the base of hybrid, exploited by scientists in developing hybrid was reported in rice. Subsequently, reports indicated significant heterosis for various agronomic traits in rice [4,5,6,7]. F_1 rice hybrids through heterosis was commercially exploited by rice scientists in India [8] China [9] U.S. [10] Japan [11] and IRRI [12]. China opened research on hybrid rice in 1964 and the first rice hybrid credit is to Chinese scientist Yuan Long ping, who developed in 1976 using 3 line breeding method [13].

Hybrid rice breeding has been based mainly on cytoplasmic male sterility (CMS) or photo-thermo genetic male sterility (P-TGMS). The breeding system using three lines (CMS line, CMS maintainer line, CMS restorer line) was developed in 1973, and marketable production of hybrid rice started in 1976 [14]. A two-line hybrid rice system by means of P-TGMS was established in the 1980s, and two-line hybrid rice was used by 1998 [15]. First form of male sterility used in the breeding of hybrid rice was wild-abortive CMS (CMS-WA), and it became the main type of CMS used in the case of number of hybrids developed and the total area of cultivation to those hybrids [16,17].

However, rapid increase in population and economic expansion have been imposing a growing pressure for increased food production. For the increment in yield potential, several major national and international programs were began with the goals to develop ‘‘super rice’’ or ‘‘super hybrid rice’’ for cracking the yield ceiling [18,19].

Super Rice

To safeguard the food security for the growing population, raising the yield ceiling of rice remained priority in China. The per capita rice consumption of 150 kg and a stable rice cropping area of 31.57 million ha, shows that the rice yield should be 7.845×10^3 kg per ha by 2030 [20]. Hence, With progresses in rice breeding in China, and encouraged by the conceptualization and experience of new plant type breeding at the International Rice Research Institute (IRRI), the Chinese Ministry of Agriculture (MOA) in 1996 established a national collaborative research programme on the breeding of super high-yielding rice (‘super rice’).

‘Super hybrid rice’ plan was aimed to combine the creation of an ideal plant type with the taking advantage of heterosis. Its execution involved equal attention to three- line and two-line hybrid rice, as well to hybrids and conventional varieties [15]. The technique introduced novel male sterile germplasm and inter-subspecies (indica - japonica) crosses to widen the genetic base of parental lines. Thus, a number of rice varieties that accomplished the yield box were developed between 2001 and 2005 [15].

Accomplishment in “super rice” breeding has been reflected a great progress in rice production in china. Two methods to get super high yield, in these varieties are, complete use of the dominant complementary effects of the two parents for progressive morphological features of the hybrid and outspreading of the genetic diversity of parents by means of intersub specific heterosis [14].

II. MARKER ASSISTED SELECTION

Plant breeding in combination with expansions in agricultural technology such as agrochemicals has made notable progress in growing crop yields forever a century. Though, plant breeders must constantly retort too many changes. First, agricultural practices variation, which generates the need for emergent genotypes with precise agronomic characteristics. Second, targeted environments and the entities within them are continually changing. For example, fungal and insect pests repeatedly change and overcome host plant resistance. New land zones are often being used for farming, revealing plants to altered growing conditions. Finally, consumer penchants and requirements get altered. Plant breeders hence face the never-ending task of frequently developing new crop varieties [21]. In spite of optimism about constant yield improvement from conventional breeding, new knowledge such as biotechnology will be required to maximize the chance of success [22,23]. DNA marker technology, one area of biotechnology, derived from exploration in molecular genetics and genomics, provides great potential for plant breeding. Due to genetic linkage, DNA markers can be used to spot the existence of allelic variation in the genes underlying various traits. By means of DNA markers to assist in plant breeding, effectiveness and accuracy could be greatly increased. The use of DNA markers in plant breeding is marker-assisted selection (MAS) and it is a component of the novel discipline of ‘molecular breeding [24].

Foremost benefit in MAS is that, at the seedling stage itself selection of looked-for trait can be carried out. This will be useful for many traits, particularly for traits that are expressed at late developmental phases. Therefore, detrimental plant genotypes can be quickly eliminated. This may have incredible benefits in rice breeding because of the typical rice production practices [24].

Molecular MAS has begun to add to the improvement of hybrid rice, specifically for major genes providing disease resistance.SSR and STS markers were used in hybrid rice to confirm purity [25]. The combination of MAS and conventional means is becoming a common approach in rice breeding [15].

The integration of resistance genes in a restorer line results in the development of resistant rice hybrids [26]. Gene pyramiding is a very useful approach to exploit the application of existing gene resources [27]. Use of conventional methods for the gene pyramiding makes the procedure chaotic and impossible to some extent. Instead, the utilisation of markers makes the process simpler and quicker.

Gene pyramiding

Gene pyramiding is the method of conjoining several genes together into a single genotype [24]. Gene pyramiding has been successfully usefed in several crop breeding programmes, and numerous varieties and lines holding multiple attributes have been produced [28,29].

A hilarious job in gene pyramiding is to identify the plants containing more than one gene since pyramiding may be possible through conventional breeding. Here comes the importance of DNA markers that facilitates selection since a single DNA sample can be used for multiple specific genes without phenotyping [24].

The combination of resistance genes during rice breeding programmes is considered to be an effective, cost-effective and eco-friendly approach to control disease. The instability of pathogen a virulence take away the resistance of cultivars having a single resistance gene after a short period of time after deployment in the field [30].

Pyramiding of four bacterial blight resistance genes *Xa-4, xa-5, xa-13* and *Xa-21has done using* DNA marker-assisted selection. Testing for resistance to the bacterial blight pathogen (*Xanthomonasoryzae* pv. *oryzae*) was done after breeding lines with two, three and four resistance genes. To develop this same bacterial blight resistance of one morehybrid rice, resistance genes *Xa21* and *Xa7*, have been introgressed into a restorer line, 'Minghui 63' by marker-assisted selection as well as conventional backcrossing, respectively. These results evidently show that for improving bacterial resistance in hybrid rice pyramiding of dominant genes is a suitable approach [31].

Another major example for gene pyramiding and usage of MAS is Green Super Rice. A mixture of approaches based on the modern advances in genomic research has been framed to address various challenges, with the long-term goal to bring up rice cultivars - Green Super Rice. With the launch of an international rice molecular breeding program in 1998, it was started, including more than 18 countries and 36 institutions. Due to the dearth of funding source to continue the program it ultimately died and later, a joint project between IRRI and the Chinese Academy of Agricultural Sciences (CAAS),was launched -Green Super Rice (GSR) for the Resource Poor of Africa and Asia, in December 2008. Project objects to develop rice varieties that hold their stable, sustainable yield potential though crop was grown with smaller amount of inputs or under unfavourable environmental conditions [32].

III. TRANSGENIC RICE

Scientific developments in cell and molecular biology have ended in the genetic engineering or crop improvement. This newest technologies allow the constant development of genetically modified (GM) plants in which specific crop can be improved by transferring DNA from any source. It provides opportunities to hasten the efficiency and scope of further crop improvement by the transfer of genes conferring resistance to diseases, pests, herbicides and environmental stress, along with quality traits such as nutritional content, improved post-harvest storage, colourand flavour. Genetic modification of plants has attained a prominent place both in basic as well as applied plant research. Novel germplasm is predicted to allow plant breeders to retort much more quickly to the need for new and improved cultivars, and fulfil the growing consumer demand for a steady supply of high-quality grains, fruits and vegetables with less blemishes from pests/diseases and reduced pesticide residues. By 2001 the area worldwide in which GM crops are grown and tested surpassed 50 million ha [33]. The combination of conventional practices along with the new GM technology can offer a satisfactorily safe and effective technology that may get resulted in a sustainable and productive agriculture [34].

China's biotechnology research program has generated a varied range of new varieties, including several GM rice varieties [35]. Duan *et al.*, in 1996 [41] regenerated a large number of transgenic rice plants by introducing the potato proteinase inhibitor II (PINII) gene (*pin2*) into several Japonica rice varieties. Wound-inducible expression of the *pin2* gene determined by its own promoter, composed with the first intron of the rice actin 1 gene (*act1*), and resulted in high-level accretion of the PINII protein in the transgenic plants. Molecular analyses showed the transferred *pin2* gene was stably inherited in the second, third, and fourth generations. A major rice insect pest, pink stem borer (*Sesamiainferens*) resistance has been shown by fifth-generation transgenic rice plants. Hence, control of insect pest in cereal plants can also be achieved by the introduction of an insecticidal proteinase inhibitor gene into it [36].

Bio fortification (i.e., increasing the bio available concentration of essential elements in edible portions of crop plants through conventional breeding or genetic engineering) [38] is another one achievement in the utilisation of genetic engineering.

Another major triumph is the yellow rice, named as golden rice.

Golden rice

"Golden rice" was developed as a solution for the vitamin-A deficiency in the poor and deprived of developing countries. A scientific revolution promises to add a crucial dietary component (provitamin A) to one of the major cuisine, rice of the poor and developing world as golden rice [37]. Golden rice could markedly cut down the distressing impact of vitamin A insufficiency since poorest families of many developing countriesare unable to buy the vegetables and fruits that contain this vital nutrient. They cannot afford anything more than plain white rice. But, the problem is rice is not usually a providing vitamin A. though many fruits and vegetables are having the genes to make this vitamin, none of the rice varieties or its close wild relatives have these genes. Conventional breeding in rice is useless in the fight against this fatal vitamin deficiency. It would take genetic engineering to unravel theunruly problem of making rice as a source of vitamin A. Though rice plants possess the whole machinery to synthesise β-carotene, it is fully active in leaves and parts of it are turned off in the grains. The principle in golden rice is that, by adding two genes, a plant phytoene synthase (psy) and a bacterial phytoenedesaturase (crt I), the pathway is turned back on and β-carotene consequently accumulates in the grain[42].

The first generation of Golden Rice disclosed that provitamin-A production in rice grains was possible, but it was acknowledged that to fight with vitamin A deficiency, higher β-carotene levels would be needed. The presence of only two genes in the process made it easier to identify the limiting factor of the biosynthetic pathway and hone the enzymatic activities of the two gene products, phytoene-synthase (PSY) and carotene-desaturase (CRTI)involved [39]. Research with PSY genes from different sources identified maize genes as the most effectual in rice grains. This led to the second generation of Golden Rice lines, mentionedas GR2, proficientto accumulate up to 37 µg/g carotenoids, of which 31 µg/g was β-carotene, unlike the first generation golden rice, where production was 1.6 βg/g [40].

CONCLUSION

World is currently at a perilous position. The population of the planet will hit 9billion people by 2050. The Philippines crossed the population 100 million. In the aspect of the decreasing land for farming, an increasing population, and increasingly inconsistent climates, we need to use every tool we have, including agricultural biotechnology, to assist our farmers and our people to endure and thrive. Our scientists are developing new Rice varieties, with aid of conventional, molecular plusgenetic engineering techniques, to increase our food security. Let us not disregard these technologies, and find ourselves once again at a technological and economic disadvantage. The scientific thrive and sustainability leads to the utilisation of these all techs and booms the scientific world to serve the farmer as well as the present and future generations.

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