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# Genetic Improvement Strategies for Increasing Rice Yield: A Review Article

Abayneh Kacharo Kampe
Southern Agricultural Research Institute, Bonga Agricultural Research Center, Bonga, Ethiopia

**Abstract**
A review article was aimed to summarize various conventional and biotechnological breeding strategies that increased rice yield in major rice producing counties having strong breeding programs. An increase in productivity is always one of the main goals of any crop breeding program including rice. Even though there was a series of breakthroughs the main breeding goals in most international programs remain similar since a long time ago: increasing grain yield potential, resistance to blast disease, grain quality, and drought tolerance. Increase in grain yield potential is the major goal of almost all rice breeding programs. The major impacts are related to the development of new strategies to increase the genetic grain yield potential of the varieties. Rice breeders have been very successful in improving the crop. The main breeding method used to improve rice is the pedigree, but development of hybrids, new plant types and mutation breeding are added to the breeder's portfolio. Breeders have been taking advantage of biotechnology tools in order to accelerate rice improvement programs as the main additional tool to conventional rice breeding strategies; however, many programs are still struggling on how to integrate them into the breeding programs especially in developing countries.

## 1. Introduction

Rice (*Oryza sativa* L.) is an important cereal food grain crop of the world with an excellent source of calories, in the form of starch, and has added benefits of providing protein with higher nutritional quality than other cereals grains. Rice is one of the important food crops in the world and ranks second in terms of area and production. It is the staple food for about 50 per cent of the population in Asia, where 90 per cent of the world's rice is grown and consumed (Virk et al., 2004). It is not only for consumption but also a good scope for domestic and international market for economic development in China, India Indonesia and USA (Hegde, S. and Hegde, V., 2013.).

In Africa, rice is the fastest growing and staple food in parts of West Africa and Madagascar, and it is increasingly becoming an important food in East, Central, and Southern Africa. In recent years, the relative growth in demand for rice is faster in SSA than anywhere else in the world according to the report of Balasubramanian *et al*., (2007).

In Ethiopia, the cultivation of rice is of a recent history. Currently, however, its use as food and cash crop is well recognized. Among the target commodities that have received due attention in promotion of agricultural production, rice is considered as the "millennium crop" expected to contribute in ensuring food security in Ethiopia. The country is endowed with a range of geographic and climatic conditions that suit to rice production with an estimated potential of more than 20 million hectares (MoARD, 2010).

Rice has become a commodity of strategic significance across much of Ethiopia for domestic consumption as well as export market for economic development. Sreepada and Vijayalaxmi, 2013 reported Ethiopia can find export market for other African countries and several factors affecting around the globe in rice production is most suitable in Ethiopia due to securing the global food crises, reduce the stress on climate change, difficulties to manage the limited land resources in all other continents, ample scope for agriculture and allied industrial sector, employment opportunity, scope for domestic consumption and export market, sustainable growth and economic development, green economy, millennium development goals, diversification in business, to avail of their technological advantage moreover opportunity to invest in agriculture sector will be the mutual benefit for investors and host country.

The ultimate goal of crop breeding is to develop varieties with high yield potential, desirable agronomic characteristics and resistance to major diseases and insects; and improved grain and eating quality. Increasing grain yield potential is the major goal of almost all rice breeder's programs around the world.

Different rice research institute i.e. IRRI, have a lot of germplasm collections of rice for the improvement of rice varieties with respect to yield and yield contributing traits. Crop improvement program also depends on the utilization of germplasm stock that is available in different rice research institutes of the world. Improving and increasing the world's supply will also depend upon the development and improvement of rice varieties with better yield potential, and to adopt various conventional and biotechnological approaches for the development of high yielding varieties having resistance against biotic and abiotic stresses (Khush, 2005). Therefore, review of various genetic improvement strategies for the development of high yielding genotypes with desirable traits for diverse ecosystem of the countries having strong breeding programs and achieved economic development in international markets (through rice exporting) receives special attention.

## 2. Conventional Hybridization and Selection Procedures

This is the time tested strategy for selecting crop cultivars with higher yield potential. It has two phases. The first phase involves the creation of variability through hybridization between diverse parents. In the second phase desirable individuals are selected on the basis of field observations and yield trials. It has been estimated that on the average about 1.0% increase has occurred per year in the yield potential of rice over a 35-year period since the development of first improved variety of rice, IR8 Peng *et al.*, 2000.

Pedigree method of breeding is the most common method of rice breeding. Rice being a self-pollinated, recombination breeding consisting of controlled crosses between parents of choice followed by selection for superior recombinants in the segregating generations for targeted traits is the widely employed approach in rice improvement. If one makes a global literature review on the breeding methods commonly used to develop rice varieties around the world pedigree selection is always at the top. More than 85% of the released rice varieties published in Crop Science Society of America have been developed through pedigree selection. When there are possibilities to carry out more than one generation per year (e.g., winter nurseries) the method is combined with modified bulk or even single-seed descent to speed up the process of having pure lines for agronomic evaluation. To combine a set of trait that make a variety unique, convergent improvement approach which involves stepwise addition of constituent traits is the best approach. Pedigree method is followed for improvement of both qualitative and quantitative traits where land / laboratory facilities and manpower are adequate while modified-pedigree or mass-pedigree method of selection is followed when selection environment is not appropriate to discriminate desirable genotypes from undesirable ones. In mass pedigree method, the segregating generations are bulked up to five generations from F2 followed by pedigree selection.

Khan et al. (2015) reported breeding efforts at IRRI led to development of flooding tolerant lines with good agronomic traits through conventional approach. The line “IR 49830-7-2-2” combines high tolerance levels with higher yield potential and resistance to diseases and insect pests and it has been extensively used as a donor parent in the breeding programme. “Sudhir” is another variety which has been developed from the “FR13A” × “Biraj” crosses.

## 3. The new plant type (ideotype) breeding

Ideotype breeding aimed at modifying the plant architecture is a time tested strategy to achieve increases in yield potential. Yang et al. (1996) suggested that in order to develop super high-yielding rice varieties it was essential to increase the biological yield. Thus selection for short statured cereals such as wheat, rice, and sorghum resulted in doubling of yield potential. Yield potential is determined by the total dry matter or biomass and the harvest index (HI).

IRRI had been working on a new rice ideotype or new plant type (NPT) with a harvest index of 0.6 (60% grain: 40% straw weight) and with an increased ability for photosynthesis to increase total biological yield. Peng et al. (2005) considered the following components on this NPT: low tillering capacity, few unproductive tillers, from 200 to 250 grains per panicle, from 90 to 100 cm of plant height, thick and strong stems, vigorous root system, and from 100 to 130 days of growth cycle. These traits would allow the rice plant to transform more energy into grain production, increasing the yield potential by about 20% but with more input and cost.

Numerous breeding lines with desired ideotype were developed and shared with the national rice improvement programs (Khush, 1995). Peng et al. (2008) reported that First-generation new plant type (NPT) lines developed from tropical japonica at IRRI did not yield well because of limited biomass production and poor grain filling. Progress has been made in second-generation NPT lines developed by crossing elite indica with improved tropical japonica. Several second-generation NPT lines out yielded the first-generation NPT lines and indica check varieties. China’s “super” rice breeding project has developed many F1 hybrid varieties using a combination of the ideotype approach and inter-subspecific heterosis. These hybrid varieties produced grain yield of 12 t·ha−1 in on-farm demonstration fields, 8% - 15% higher than the hybrid check varieties. The success of China’s “super” hybrid rice was partially the result of assembling the good components of IRRI’s NPT design in addition to the use of intersubspecific heterosis.

Chinese scientists has been recommended the following plant type to be combined with heterosis breeding to produce super rice hybrids capable of yielding 100 kg/ha yield.

Plant height about 100 cm, with culm length of 70 cm.

Top three leaves;

Long: Flag leaf is 50 cm and 2nd and 3rd comes 55 cm in length. The top two leaves are higher than the top of the panicle.

Erect: Leaf angle of the flag, −2nd and −3rd leaves are around 50, 100 and 200, respectively.

Narrow and V shaped: The leaves look narrow but they are wide when flattened.

Thick: 55 g·m−2 of specific leaf weight for the top three leaves.

Plant type: Moderately compact type with moderate tillering capacity; droopy panicles, the panicle top about 60 cm from the ground after filled; erect leaf canopy without appearance of panicle.

Panicle weight and number; grain weight 5 g per panicle, 270 - 300 panicles m−2.
Leaf area index (LAI): The LAI of top three leaves is about 6
Harvest index: about 0.55

## 4. Heterosis Breeding

Heterosis breeding, which exploits the phenomenon of hybrid vigor, has proven to be a practical method of crop improvement, especially for increasing yield potential in many crops. This phenomenon has been exploited primarily in several cross and often cross-pollinated crops such as maize, pearl millet, onion, sorghum, cotton, etc. but its application is also being extended to several self-pollinated crops including rice. More than 50% of the total rice area in China is planted to hybrid rice, and many countries outside China are developing and exploiting hybrid rice technology). Rice hybrids with a yield advantage of about 10% - 15% over best inbred varieties were introduced in China in mid 1970s and are now planted to about 45% of the rice land in that country. Rice hybrids adapted to tropics have now been bred at IRRI and show similar yield advantage. The increased yield advantage of tropical rice hybrids is due to increased biomass, higher spikelet number and to some extent higher grain weight. Increased adoption of hybrids in the tropics should contribute to increased productivity. In the early 1990s, several other countries (Bangladesh, Egypt, India and Vietnam) have been developed and introduced hybrid rice technology to their farmers. During the first decade of the 2000s, several African countries (Côte d'Ivoire, Liberia, Madagascar, Mozambique, Nigeria, Tanzania and Uganda) started to evaluate and cultivate rice hybrids from China. Only Egypt has succeeded in developing a hybrid rice breeding programme and produces Egyptian hybrids on a commercial scale. Grain yields obtained with hybrids have been in the order of 12–14 tons per hectare (Bastawisi et al., 2003).

### 4.1 Three, two and one-line breeding systems are the main strategies for exploitation of heterosis in rice

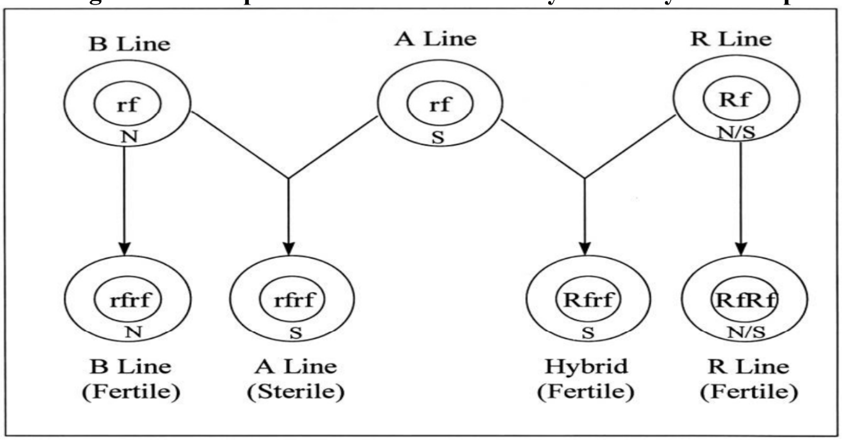
Currently three different technologies viz., ‗one line", „two line" and „three line"; are adopted for development of rice hybrids and exploration of heterosis in rice (Yuan, 2002).

*4.1.1 Three-line system*

Three-line system involving a cytoplasmic male sterile (CMS) line (A), maintainer line (B) and restorer line (R). This is a more popular method worldwide in almost all the crops in which hybrids have been developed and commercialized (Sattari *et al*., 2008; Fujii *et al*., 2009; Sheeba *et al*., 2009). Most of the rice hybrids are being developed with three-line system worldwide (Li and Xin, 2000).

The first CMS line used to develop commercial F1 rice hybrid was developed in China in 1973 from a CMS plant occurring naturally in a wild population of *Oryza sativa* f. *spontanea* in Hainan island, which was designated as Wild Abortive (WA) system (Anonymous, 1977). Since then a number of CMS lines have been developed worldwide from various wild and cultivated accessions (Lin and Yuan, 1980). There are numerous CMS lines reported from *indica* and *japonica* backgrounds, among which only WA type was extensively used for commercial hybrid rice production in China and India, covering about 90 % of hybrid rice area. Pollen abortion of CMS lines could occur at any time from sporogenous cell to the tri-nucleate stage of pollen development (Pan *et al.,* 1982). Rao (1988) has reported that abnormal development or damage of inter cellular tapetal cells often results in the pollen abortion of rice male sterile lines. Nuclear restorer genes for fertility (*Rf)* can counteract pollen sterility in cytoplasmic male sterile plants (Newton, 1988). *Rf* genes are indispensable for hybrid seed production systems, because F1 hybrids based on CMS system are fertile when they have a heterozygous *Rf* gene. The pollen fertility in these F1 hybrid plants differs in their CMS phenotype.

**Fig 1: The diagrammatic representation of three-line system of hybrid rice production.**



*4.1.2 Two-line system*

Another method of heterosis breeding, which is becoming popular for developing rice hybrid is called two-line system (Wang *et al*., 1995). There are two techniques that have been used in this system. The first one is chemical emasculation and the second one is Thermo sensitive and Photo sensitive genic male sterility (T (P) GMS) system. Chemical emasculation of plants was reported as early as the 1950s. China began using chemical emasculation to produce rice hybrids in the 1970s. The Thermo sensitive and Photo sensitive genic male sterility (T (P) GMS) lines can be used for male sterile line multiplication and F1 seed production under different temperature or day length regiments. This system is genetically controlled by nuclear gene(s) and thus there is no negative effect from the cytoplasm and no risk of unilateral cytoplasmic breakdown. The first TGMS line of rice, Annong-IS was isolated as a spontaneous mutant in China and the sterility is controlled by a recessive gene. In rice, temperate of more than 280C, the TGMS lines are male sterile, while at lower temperature (below 240C), these lines transform into fertile. Some other TGMS lines are Annong S, Hennong S, Novin PL 12, IR 68945, Pei Ai 64S etc.

In tropics, where consistent temperature differences are found at different altitudes or during different seasons in the same location, TGMS system is ideal for developing two line hybrids. The first PGMS source was reported in the *japonica* cultivar Nongken 58S. Some other PGMS lines are Zennongs, X 88 and 700 IS. Using this system, the hybrid seed production can be undertaken in the longer day length seasons, while the seed of PGMS line can be multiplied in the shorter day length areas / seasons.

Since then several TGMS genes (more than 10) have been identified from diverse sources (Li *et al*., 2007). Tang *et al*., (2006) reported that TGMS trait in rice is inherited in a normal mendelian fashion and is under the control of single recessive gene. The known TGMS genes are recessive in nature (e.g. tms1, tms2, tms3, tms5 etc.) (Yang *et al*., 1990; Maruyama *et al*., 1991; Lee *et al*., 2005). For a large country like India, with vast temperature differences across locations, seasons and elevations, TGMS system is better suited than PGMS system (Viraktamath and Virmani, 2001).

*4.1.3 One-line system*

One-line methodology of hybrid seed production involves utilization of apomictic system. In this system hybrid plant is produced by crossing two parental lines and it can be maintained indefinitely by apomixes without losing the genotypic constitution of the hybrid. To enhance the need for the hybrid rice seed production, Yuan (1987) proposed utilization of apomixis in rice. It results in no deterioration of heterosis with year after year seed production. This system is still in a preliminary state and has not generated any stable hybrid till now.

**4.2 Advances in two-line hybrid rice breeding**

The discovery of environment-sensitive genic male sterility in rice led to the development of a simpler and more efficient two-line hybrid breeding system compared with the cytoplasmic male sterility or three-line system. Several elite photoperiod-sensitive (PGMS) and thermosensitive genic male sterile (TGMS) lines have been developed in China. The commercial two-line hybrids developed using these lines occupied about 330,000 ha in 1996. Multiplying PGMS and TGMS lines in a pure form requires some special handling. These methods have been developed in China. Similar methods of seed production have been adopted for both two-line and three-line hybrids. The key point is to determine the time when a PGMS or TGMS line will show complete sterility for about 1 mo at a given location. Seed yield of two-line hybrids in China is 2.25 - 3.0 $t\cdot ha^{-1}$. Under tropical conditions, in which day length differences are marginal, the TGMS system is considered to be more useful than the PGMS system. Genetic analysis at IRRI confirmed the monogenic recessive control of the TGMS trait. The TGMS gene of the IRRI mutant, IR32364 TGMS, was found to be non-allelic to the TGMS genes identified in China (tms 1) and Japan (tms 2). IRRI has developed some TGMS lines in indica rice that possess the tms 2 gene; these lines are being evaluated in national agricultural systems. As expected, the TGMS system gave a higher frequency of heterotic hybrids than the CMS system.

**5. Mutation Breeding**

Mutation breeding is very useful in situations where only one or two simple changes in well adapted local cultivars are needed so as to include gene complexes for tolerance to biotic and abiotic stresses, grain quality etc. Today the technique became part of the tools kit breeders have to enhance specific rice characteristics in well-adapted varieties. A wide array of physical and chemical mutagens has been evaluated on rice and a wide array of economically useful point mutations affecting plant height, leaf, panicle, grain type has been recovered.

According to Wang (1992) during the period 1966–1990, there were 78 varieties released in China originated from mutation breeding. From 1991 to 2004, there was a similar number (77) of new varieties were released through application of mutation (Chen et al., 2006). The most popular mutagen is still the gamma rays and the mutated characteristics are the ones responsible for the expression of agronomic (e.g., resistance to pests) and grain quality phenotypes.

In Indonesia the first mutant variety (Atomita 1) was released in 1982 and several varieties were developed after onwards and most of them were improved for biotic stresses such as resistance to brown plant hopper; in all cases the mutagen agent was the gamma rays (Ismachin and Sobrizal, 2006).

Vietnam is one of the most important rice producing country in the world. Reports from Tran et al. (2006) indicated that during the period 1990 and 2002 the Agricultural genetic institute developed and released 10 varieties, most of them have better grain quality, in addition to other agronomic traits; once more the gamma rays were the most common mutagen agent used.

## 6 Integration of New Biotechnological approaches in Rice Breeding

### 6.1 Simple biotechnological techniques as means to break sexual barriers in rice

Rice has a series of species that can and have been used to address specific breeding problems such as resistance to pests and tolerance to abiotic stresses. However, one of the main limitations on the use of wild relatives in breeding programs is the lack of cross ability between species due to chromosomal and genetic differences. One alternative to overcome these sexual barriers is to use embryo rescue and protoplast fusion, which are simple biotechnology techniques that have been used successfully in rice. Jones et al. (1997) reported the breeding program of WARDA that combined the two cultivated rice species O. sativa and O. glaberrima in 1991 by employing embryo rescue technique. The newly developed materials were called ‘‘new rice for Africa’’ and were popularized as NERICA varieties.

### 6.2 Recombinant DNA technology/genetic Engineering

Protocols for rice transformation have been developed which allow transfer of foreign genes from diverse biological systems into rice. Datta et al. (1990) reported direct DNA transfer methods such as protoplast based and biolistic as well as agrobacterium-mediated are being used for rice transformation according to Hei et al. (1990). Major targets for rice improvement through transformation are disease and insect resistance.

*6.2.1 Transgenic rice for increased resistances to insects and diseases*

As early as 1987, genes encoding for toxins from *Bacillus thuringiensis* (BT) were transferred to tomato, tobacco and potato, where they provided protection against Lepidoptern insects. A major target for BT deployment in transgenic rice is the yellow stem borer. This pest is widespread in Asia and causes substantial crop losses. Improved rice cultivars are either susceptible to the insect or have only partial resistance. Thus BT transgenic rice has much appeal for controlling the stem borer. Codon optimized BT genes have been introduced into rice and show excellent levels of resistance in the laboratory and greenhouse Datta et al. (1997).

Tu et al. (2000) tested BT rices under field conditions in China and have excellent resistance to diverse populations of yellow stem borer. Besides BT genes, other genes for insect resistance such as those for proteinase inhibitors, α-amylase inhibitors and lectins are also beginning to receive attention. Insects use diverse proteolytic or hydrolytic enzymes in their digestive gut for the digestion of food proteins and other food components. Plant derived proteinase inhibitors or α-amylase inhibitors are of particular interest because these inhibitors are a part of the natural plant defense system against insect predation. Xu et al. (1996) reported transgenic rice carrying cowpea trypsin inhibitor (Cpti) gene with enhanced resistance against striped stem borer and pink stem borer.

Several viral diseases cause serious yield losses in rice. A highly successful strategy termed coat protein (CP) mediated protection has been employed against certain viral diseases such as tobacco mosaic virus in tobacco and tomato. A coat protein gene from rice strip virus was introduced into two japonica varieties by electroporation of protoplasts were reported by Hayakawa et al., (1992). The resultant transgenic plants expressed CP at high level and exhibited a significant level of resistance to virus infection and the resistance was inherited to the progenies.

*6.2.2 Transgenic rice for improved nutritional quality*

Malnutrition disorders are the cause of 24,000 deaths a day. “Golden Rice” represents a genetic engineering concept for the development of nutrient-dense staple crops which can make an important contribution to the reduction of malnutrition in developing countries. Major micronutrient deficiency disorders concern protein, energy, iron, zinc, vitamin A and iodine. These deficiencies are especially severe in countries where rice is the major staple. Rice contains neither b-carotene (provitamin A) nor C40 carotenoid precursors in its endosperm. Rice in its milled form (as it is usually consumed) is therefore entirely without vitamin A and its carotenoid precursors. Millions of rice consumers who depend on rice for a large proportion of their calories suffer from vitamin A deficiency.

Ye et al., (2000) produced transgenic rice (Golden Rice) with the provitamin A (b-carotene) biosynthetic pathway engineered into its endosperm. Agrobacterium-mediated transformation was applied to introduce three genes: phytoene synthase (psy), phytoene desaturase (crt1) and lycopene cyclase (lcy). HPLC (high performance liquid chromatography) analysis revealed the presence of b-carotene in transgenic seeds. The transformed rice Taipei 309 is no longer cultivated. Efforts were made at IRRI to transfer the genes for b-carotene into widely grown varieties, such as IR 64, through conventional backcrossing and transformation. Goto, et al., (1999) introduced the entire coding sequence of the soybean ferritin gene into kita- ake, a rice cultivar via Agrobacterium mediated transformation. The introduced ferritin gene was regulated by the rice seed storage protein glutelin promoter, GluB-1, and terminated by the Nos polyadenylation signal. Synthesis of soybean ferritin protein was confirmed in each of the transformed rice seeds by western blot analysis, and specific accumulation in endosperm was determined by immunological tissue printing. The iron content of T1 seeds was up to three times higher than in untransformed seeds.

### 6.3 Molecular Marker Assisted Breeding

Numerous genes for disease and insect resistance are repeatedly transferred from one varietal background to the other. Most genes behave in dominant or recessive manner and require time consuming efforts to transfer. Sometimes the screening procedures are cumbersome and expensive and require large field space. If such genes can be tagged by tight linkage with molecular markers, time and money can be saved in transferring these genes from one varietal background to another. The presence or absence of the associated molecular marker indicates at an early stage, the presence or absence of the desired target gene. A molecular marker very closely linked to the target gene can act as a “tag” which can be used for indirect selection of target gene.

Two of the most serious and widespread diseases in rice production are rice blast caused by the fungus *Pyrcularia oryzae*, and bacterial blight caused by *Xanthomonas oryzae* pv. oryzae. Development of durable resistance to these diseases is the focus of a coordinated effort at IRRI using molecular marker technology. Efforts to detect markers closely linked to bacterial blight resistance genes have taken advantage of the availability of near isogenic lines having single genes for resistance. Segregating populations were used to confirm co-segregation between RFLP markers and genes for resistance. Protocols for converting RFLP markers into PCR based markers and using the PCR markers in marker-aided selection have been established Zheng, et al., (1995). The PCR markers were also used for pyramiding genes for resistance to bacterial blight. Thus xa4, x5, xa13, and Xa21 were combined into same breeding line Huang et al., (1997). The pyramided lines showed a wider spectrum and higher level of resistance than lines with only a single gene for resistance. According to Sanchez, et al., 2000 and Singh et al., 2001, MAS has also been employed for moving genes from pyramided lines into new plant type; as well as into improved varieties grown in India. Novel alleles and genetic diversity widely exist in wild relatives of cultivated plants. For example, wild relatives of rice within the genus Oryza are not only a rich source of information on the origins of variation within the genus but also a viable source of a wide variety of agronomically important germplasm for future breeding.

Molecular markers also used to unlock the genetic diversity existing in a wide spectrum of germplasm collections and have been proven particularly useful for accelerating the backcrossing of a gene or QTL from exotic cultivars or wild relatives into an elite cultivar or breeding line. Favorable genes or alleles from wild species of rice have been detected after backcrossing to elite cultivars as reported by Moncada et al., (2001). Similarly, this approach can identify alleles from exotic cultivars that result in improved phenotype, even though the parent may not possess inferior phenotype for this trait. This approach is thought to be promising in rice because a number of rice cultivars are widely grown for their adaptation, stable performance, and desirable grain quality. Chen et al., (2000) also used MAS approach to transfer the bacterial blight resistance gene Xa21 into Minghui 63, a widely used parent for hybrid rice production in China. Ahmadi et al., (2001) used a similar approach to introgression two QTLs controlling resistance to rice yellow mottle virus into the cultivar IR64. Such approaches, however, can only sample a small number of accessions.

#### *6.3.1 Application of a simplified marker-assisted backcross technique*

Bacterial blight (BB) caused by Xanthomonas oryzae pv. Oryzae (Xoo) is one of the most destructive bacterial diseases that affect hybrid rice production. (Mew ,1993). The marker-assisted backcross breeding (MABB) technique is usually used to improve disease resistance while preserving identical backgrounds by repeatedly crossing to a recurrent parent (Chevalet and Mulsant, 1992). Although background selection is very useful for rapid recovery of the recurrent parent genome, its use in breeding programs is constrained by the limitation of detecting polymorphisms with markers such as simple sequence repeats (SSRs), its cost, and the need for timely execution (Singh , 2012).(2014 5) Zhijuan (2014) with using this technique introgressed bacterial blight resistance gene Xa2311into HN189 and improved restorer lines, HBH145 (with one generation of backcrossing) and HBH146 (with two generations of backcrossing), were obtained that had a significant bacterial blight resistance advantage over HN189. They displayed using of the marker-assisted backcross breeding technique with one generation of backcrossing and without background selection in rice breeding programs shortened the breeding period of the rice.

## 7. Conclusion

Rice has become a commodity of strategic significance across much of Ethiopia for domestic consumption as well as export market for economic development. The ultimate goal of crop breeding is to develop varieties with high yield potential and desirable agronomic characteristics. In rice breeding, the most important qualities sought by breeders have been high yield potential; resistance to major diseases and insects; and improved grain and eating quality. Various strategies to increase the yield potential include: conventional hybridization, heterosis breeding, ideotype breeding, Mutation breeding, genetic engineering and molecular marker assisted breeding. Conventional breeding is still a widely used strategy for developing crop varieties with a higher yield potential. Modifying the plant architecture is also an important breeding strategy to achieve increased rice yield potential. Mutation breeding is also very useful in situations where only one or two simple changes in well adapted local cultivars are needed so as to include gene complexes for tolerance to biotic and abiotic stresses, grain quality etc. The integration of molecular biology, genomic research, transgenic breeding and molecular marker applications with conventional plant breeding practices has created the foundation for molecular plant breeding and certainly accelerated rice improvement programs across the world. Recombinant DNA technology has resulted in production of transgenic rice with new genetic traits and for resistance to biotic and abiotic stresses. Marker-assisted selection (MAS) has become integral component of germplasm improvement. A large number of genes for various traits have been tagged with molecular markers to apply MAS for trait improvement. Map-based cloning has resulted in isolation of several genes for resistance to biotic and abiotic stresses as well as yield-related traits. This has opened the possibility of applying MAS for yield enhancement in rice.

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