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Current status and future prospects of research on genetically modified rice: A review

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ABSTRACT

Genetically modified crops are the most auspicious development of scientists of today. Rice being the staple food crop globally, it is needed to give immense importance for its improvement. Development of rice varieties tolerant to pests and diseases will ensure safety to farmers against the harmful effects of chemicals used as insecticides and fungicides. Certain abiotic factors like drought, cold, heat, salinity, which hinders the growth of rice can be battled by developing GM rice carrying genes that impact tolerance to these factors. Moreover, increased production and utilization of golden rice would provide the required nutrients especially for the poor to meet their nutritional requirements. But commercialization of GM crops is still an issue as people are yet to accept them globally. Finally, the future prospect of GM rice will flourish unless it is met by some loop holes.

Key words: Abiotic, Bio-fortification, *Cry*, Resistance, Transgenic.

As we move into the 21st Century and world population increases towards 9 billion, cereal grain production will need to increase by one billion tones (Borlaug and Dowsewell, 2001). Almost half of the world's populations rely on rice for food source. Rice is grown in tropical and subtropical regions around the world mainly in China, India, and Southeast Asia. These regions make up 90 percent of the world's rice production, mostly produced by small-scale farmers. China ranked first in rice production whereas India is the second largest producer, consumer and world's leading exporter of rice.

Modern plant breeders and farmers are still trying to improve the ability of rice to defend it against biotic and abiotic factors; also to improve the quality of rice. The Green Revolution, which brought together improved varieties, increased use of fertilizer, irrigation and synthetic pesticides, is credited with helping to feed the current global population of more than 7 billion(Phipps and Park, 2002). Thus, the combined effects of improved varieties, increased fertilizer use and irrigation coupled with increased pesticide use have been instrumental in allowing world food production to double in 35 years (Tillman, 1999). But the negative effects of these inputs were unforeseen at the time of their adoption. In the 1970's the World Health Organization (WHO) estimated that there were globally 500,000-pesticide poisonings/year, resulting in 5,000 deaths (Farah, 1994).

Genetically modified (GM) crops have been discussed as one of the possible ways for combining higher yields, improved food and feed quality with environmentally friendly agronomic practices (Phipps and Beever, 2000). Since the introduction of biotech crops in 1996, almost two decades ago, an estimated 17.3 million farmers from 28 countries grew biotech crops on 181.5 million ha in 2014 (ISAAA Brief 49-2014); also genetically modified rice varieties are commercially available in some of the countries (Table 1). As rice is one of the major food grains of the world, genetic engineering techniques should be applied to increase the quality and quantity of rice. Some of the important researches on transgenic rice are discussed in this paper.

A) Herbicide-resistant rice

Herbicide resistant rice is a type of rice that is resistant to a particular herbicide or herbicides; where herbicide only kills weeds in the rice field. This herbicide resistant rice was mainly developed to control weed, particularly where rice is direct seeded. After maize and soybean, transgenic herbicide-resistant rice is also adopted in some of the countries like USA, Malaysia and it may be introduced in other Asian countries in the coming years. CLEARFIELD® rice was intentionally created from a mutation that confers tolerance to imidiazolinone herbicides. In April 2012 it was the only herbicide-resistant rice available for farmers in the US to address weedy rice called "red rice". It was developed by Louisiana State University, University of Arkansas and Mississippi State University in cooperation with BASF. Clearfield rice was first grown in the USA in

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TABLE 1: Commercialized transgenic rice varieties

Developer	GM Trait	**Gene Introduced**	**Function**	**Trade Name**	**Reference**
NIAS (Japan)	Anti-allergy , Antibiotic resistance	*7crp*	Triggers mucosal immune tolerance to cedar pollen	not available	Takagi *et al.,*2005
		aph4 (hpt)	Allergens allows selection for resistance to the antibiotic hygromycin B		
Huazhong Agricultural University (China)	Lepidopteran insect resistance	*cry1Ab*	Confers resistance to lepidopteran insects by selectively damaging their midgut lining	BT Shanyou 63	Grohmann and Mäde, 2009
		cry1Ac	Confers resistance to lepidopteran insects by selectively damaging their midgut lining		
Huazhong Agricultural University (China)	Lepidopteran insect resistance	*cry1Ab*	Confers resistance to lepidopteran insects by selectively damaging their midgut lining	Huahui-1	OECD, 2004
		cry1Ac	Confers resistance to lepidopteran insects by selectively damaging their midgut lining		
Bayer Crop Science (including fully and partly owned companies)	Glufosinate herbicide tolerance	*Bar*	Eliminates herbicidal activity of glufosinate (phosphinothricin) herbicides by acetylation	Liberty Link™ rice	Bayer Crop Science Homepage
Agricultural Biotech Research Institute (Iran)	Lepidopteran insect resistance , Antibiotic resistance	*aph4 (hpt)*	Allows selection for resistance to the antibiotic hygromycin B	not available	Ghareyazie *et al.*, 1997
		cry1Ab (truncated)	Confers resistance to lepidopteran insects by selectively damaging their midgut lining		

Source: ISAAA Brief 46-2013

2002 and then released in Malaysia in 2010 and it may be introduced in other Asian countries in the coming years.

BASF Malaysia reported that yields with Clearfield rice had doubled from 3.5 metric tons/ha to 7 metric tons/ha (Sudianto *et al.,* 2014). Its use to control weedy rice has increased in the past 12 years to constitute about 60% of rice acreage in Arkansas, where most U.S. rice is grown (Burgos *et al.,* 2014).

Although a GM rice cultivar (LL62) has been approved in the US developed by Bayer crop sciences, farmers have not yet begun using it.

In addition to these, there are other types of herbicide-resistant rice including Liberty Link® and Roundup Ready® rice, but still they are not commercially available (ISAAA Brief 46-2013).

B) Disease resistance

In rice, more than 70 diseases have been recorded; caused by fungi, bacteria, viruses or nematodes (Zhang *et al.,* 2009). Though resistant cultivars and application of chemical pesticides have been widely used, using the techniques of genetic engineering to develop transgenic rice resistant to diseases is more significant to durable resistance, giving protection for a long time and over a broad geographic area.

a) Viral diseases: Some of the important viral pathogens of rice are Tungro viruses, Rice Stripe Virus (RSV), Rice Hoja Blanca Virus (RHBV) and Rice Yellow Mottle virus (RYMV). Protein-mediated and RNA-mediated resistance are the two strategies used to develop successful transgenic viral resistance in rice (Sanford and Johnston, 1985). Both of the strategies depend on the concept of 'pathogen-derived resistance'.

In coat proteins (CP) mediated viral resistance, CPs are involved in many aspects of virus-related biology, including encapsidation, virus replication, dissemination, and cell-to-cell and/or systemic movement (Callaway *et al.,* 2001). For the rice tungro spherical virus (RTSV) CP genes *CP1, CP2* and *CP3* were introduced into rice and a significant delay of virus replication under greenhouse conditions in transgenic plants expressing the RTSV-*CP1, -CP2* and -*CP3* genes singly or together were observed (Sivamani *et al.,* 1999). RSV CP gene which was introduced into two japonica varieties and the CP found to express at high levels and exhibited a significant level of resistance to virus infection in the transgenic plants (Hayakawa *et al.,* 1992).

Replication enzyme-mediated resistance was found effective against geographically distinct RTSV isolates (Huet *et al.,* 1999).

RNAi-mediated resistance has been reported to be effective against viral diseases in plants. Transgenic rice plants expressing DNA encoding ORF IV of rice tungro bacilliform virus (RTBV), both in sense and in anti-sense orientation showed different resistance responses against RTBV. In RTBV-O-Ds1 line, there was an initial rapid build-up of RTBV levels, followed by a sharp reduction, resulting in approximately 50-fold lower viral titers and in RTBV-ODs2 line, RTBV DNA levels gradually raised from an initial low to almost 60% of that of the control at 40 days after inoculation (Tyagi *et al.,* 2008).

Transgenic rice plants carrying Pns12 and Pns4 (non-structural protein expressed in cultured insect cells) specific RNAi constructs were found to accumulate specific short interfering RNAs; and the progenies of the transgenic rice plants with Pns12-specific RNAi constructs were strongly resistant to RDV(Rice dwarf virus) infection (Shimizu *et al.,* 2008).

b) Bacterial and fungal diseases: Most serious constraints on high productivity of rice are blast (*Magnaporthe grisea*), bacterial leaf blight (*Xanthomonas oryzae* pv. *oryzae*) and sheath blight (*Rhizoctonia solani*). R genes conferring broad spectrum resistance have great potential in accelerating improvement of widely-used elite rice varieties for high level of disease resistance. During the last decade, more than 100 disease resistance (R) genes, e.g. *Pib, Pi-ta, Pi2, Pi9, Pi-d2, Pi36, Pi37* and *Piz-t* for blast resistance and *Xa1, Xa3/ Xa26, xa5, Xa21, Xa27*etc for bacterial leaf blight resistance, have been characterized at molecular and genetic level (Zhang *et al.*, 2009). These cloned R genes confer high level of resistance and are very useful novel resources for improving blast and leaf blight resistance by means of genetic engineering.

Pathogenesis-related (PR) proteins are a class of novel proteins having activities of hydrolytic enzymes including chitinase and â 1, 3-glucanase, which can hydrolyze major components of fungal cell walls, chitin and â-1, 3 glucan, respectively. Transgenic rice plants which constitutively expressed these genes showed significant resistance against fungal pathogens. Dm-AMP1, a defensin from *Dahlia merckii*, was introduced into rice. Expression levels of Dm-AMP1 ranged from 0.43 to 0.57% of total soluble protein in transgenic plants. The plants expressing Dm-AMP1 showed significantly improved resistance to *M. oryzae* and *R. solani,* by 84 and 72%, respectively (Zhang *et al.,* 2009).

Constitutive expression of puroindolines and cecropins, which are antimicrobial proteins, in transgenic rice, conferred partial or moderate but not absolute resistance against pathogens (Krishnamurthy *et al.,* 2001 and Coca *et al.,* 2006).

Transgenic rice plants expressing AtNPR1 showed enhanced disease resistance against *M. grisea* and *X. oryzae* pv. *oryzae* by priming the expression of SA-responsive endogenous genes, such as the *PR1b, PR5, PR10* and *PBZ1*. Genetic modification of JA-related fatty acid metabolism by suppression of 3 fatty acid desaturases, allene oxide cyclase or 12-oxo-phytodienoic acid reductase also increased disease resistance against *M. grisea* (Zhang *et al*., 2009).

Aspergillus niger derived GOX gene showed constitutive and pathogen-induced expression in transgenic rice plants (Kachroo *et al.,* 2003). However, this lead to an increase in the endogenous levels of H_2O_2, which in turn caused typical cell death and activated the expression of several defense genes.

Another approach of broad spectrum resistance is gene pyramiding. Some of the successful examples are pyramiding *Xa21* gene, a chitinase gene, and a *Bt*-fusion gene into IR72 through conventional crossing of two independent transgenic homozygous rice lines that conferred multiple resistances against *X. oryzae* pv. *oryzae, R. solani* and yellow stem borer (Datta *et al.,* 2002). Combination of marker-assisted breeding and genetic transformation yielded rice lines resistant to blast and leaf blight diseases by pyramiding *Pi1, Piz5* (major blast resistance genes), and *Xa21* (Narayanan *et al.,* 2004).

C) Insect resistant rice

Rice crop yield losses mainly occurred due to infestation of stem borers (*Chilo suppressalis*), a major group of lepidopteron pests and estimated to be 5-10% (Pathak and Khan, 1994). In addition, another major group of insect pests like leaf folder (*Cnalhalocrocis medinalis*) and plant hoppers cause large annual yield losses across the country. Although different synthetic insecticides are applied frequently in order to control insect pests of rice, tremendous economic and environmental losses still occur regularly. The excessive use of these insecticides not only increased production cost but also pollutes environment and threatens human health. Conventional plant breeding approaches for developing resistant varieties were not successful due to the limited sources of resistance to striped stem borer, yellow stem borer (*Tryporyza incertulas*) and leaf folder.

So far many useful insect resistant genes have been identified and isolated from different plants, animals and from microorganisms. In the year 1989, scientists from the Chinese Academy of Agricultural Sciences (CAAS) developed *Bacillus thuringiensis (Bt*) rice plants (Yang *et al.,* 1989) in China and that was the earliest successful Bt rice transformation in the world. *Bt* genes have been successfully transferred and expressed in different rice varieties and but here we tried to highlight few recent transformation in Table 2.

Transgenic insect resistant rice developed using *Bt* genes have been tested under field conditions, which showed resistance with potential yield performance. In China since 1989, insect resistance genetically modified (IRGM) rice lines expressing insecticidal genes with lepidopteron activity

TABLE 2: *Bt* rice cultivar with different *Cry* genes for resistance against lepidopteron insects.

GENE	Promoters	Cultivar	Reference
cry2A	CaMV35S	Basmati370, M-7	Sheng *et al*., 2003
cry1Ab	Pollen specific, Ubiquitin, PEPC	Basmati370	Husnain*et al*., 2002
cry1Ac	Ubiquitin	Elite Eyi 105, Bengal	Loc*et al*., 2002
cry1Ac	Ubiquitin	IR 64, Pusa Basmati-1, Kamal Local	Khanna and Raina, 2002
cry1Ab, cry1Ac	Ubiquitin	Basmati370	Ahmad *et al*., 2002
cry1B	Maize proteinase inhibitor	Ariete	Breitler*et al*., 2001
cry1Ab	Ubiquitin	KMD1, KMD2	Shu *et al*., 2000; and Ye *et al*., 2001
cry1Ab	CaMV35S	Taipie-309	Wu *et al*., 2000
cry1B	Ubiquitin	Ariete, Senia	Breitler*et al*., 2000
cry1Ab/cry1Ac hybrid gene	Actin-1	CMS restores Minghui63, Shanyou 63	Tu*et al*., 2000

Adopted from: Bakshi and Dewan, 2013; Sasha *et al*., 2004; and Giri & Laxmi, 2000 with slight modification.

[e.g., *cry1Aa, cry1Ab, cry1Ac, cry1Ab/Ac, cry1C, cry2A* (cry-crystal), *CpTI* (cowpea trypsin inhibitor)] under control of various promoters have been developed and tested at various stage (Chen *et al.,* 2011). The most frequently used *Bt* genes are *Cry1A, Cry1Ab and Cry1Ac* and *Cry1Ab/Ac* fusion gene (Table 2). These *Bt* rice lines showed resistance against striped stem borer, yellow stem borer and leaf folder (Bakshi and Dewan, 2013).

In China, a number of IRGM rice varieties have been tried in field condition and four varieties engineered to be resistant to major pests and have advanced to the preproduction trail in farmers' fields in 2001. One variety, GM Xianyou 63, was created to be resistant to rice stem borer and leaf roller by insertion of a Chinese created *Bt* gene (Tu *et al.,* 2000). The GM Xianyou 63 rice variety does appear to increase yields (between 6 and 9%) [Huang *et al.,* 2005].The other variety, GM II-Youming 86, also was created to be resistant to rice stem borers, but in this case, the resistance was created by introducing a modified CpTI gene into rice (Deng *et al.,* 2003). On October 22, 2009, China's Ministry of Agriculture issued two biosafety certificates for commercial production of *Bt* rice lines Huahui No. 1 and *Bt* Shanyou 63 in Hubei Province (Chen *et al.,* 2011). Huahui No. 1 is a cytoplasmic male sterile (CMS) restorer line and *Bt* Shanyou 63 is a hybrid of Huahui No. 1 and Zhenshan 97A which was used as CMS line. Both lines express a *cry1Ab/Ac* fusion gene. China has now become the first nation in the world to commercialize IRGM rice, which is likely to result in a positive influence on global acceptance and the speed at which biotech food and feed crops are adopted (James, 2009).

Studies show that many insects developed resistance to *Bt* toxins in green house or laboratory conditions and were able to survive on *Bt* crops which revealed that insects have potential to evolve resistance against *Bt* crops (Bates *et al*., 2005). Although *cry1* and *cry2* are the primary genes used for IRGM rice, the *Bt vip* gene (*vip3H*) [Fang, 2008], plant-derived insect-resistant lectin genes (e.g., *gna, pta*), protease inhibitor genes [e.g., CpTI, pinII (potato inhibitor II) and SbTI (soybean trypsin inhibitor)], and animal-derived insect-resistant gene (e.g., spider toxin gene, SpI) are also being used for IRGM rice (Chen *et al.,* 2011). New cry genes (e.g., *cry4Cc1, cry30Ga1,* and *cry56Aa1*) have been identified as having insecticidal activity on stem borers (Li et al. and Zheng et al., 2009). Therefore, it may be possible to substitute genes for *cry1* and *cry2* or they could be used for gene pyramiding to create develop durable resistance. Resistance management is major and cheapest technical challenge for *Bt* rice. Development of transgenic varieties with two *Bt* toxin in combination, avoid the occurrence of cross resistance and t has been reported that *Cry1A, Cry1C* and *Cry2A* are suitable to combine.

In addition to the insecticidal genes, promoters play a vital role in determining where and when the genes are expressed in the plant (Bates *et al.,* 2005). Thus, promoters can influence the environmental fate of insecticidal proteins and the evolution of resistance (Gould 1998; Bates *et al.,* 2005). Constitutive promoters generally allow the genes to be expressed continuously in most parts of the plant. An alternative to this is to have them expressed only in certain tissues attacked by insects. The tissue-specific promoter rbsc (ribulose-1, 5-bisphosphate carboxylase/oxygenase) was used for cry1C rice to reduce potential ecological and food risks (Ye *et al.,* 2009).

Much evidence reveals that there is a positive impact of the insect-resistant GM rice on productivity and farmer health. Insect resistant GM rice yields around 6 to 9% higher than conventional varieties, with an 80% decrease in insecticide use (Huang, 2005). So it can be said that there is a benefit of transgenic insect resistant crops in terms of higher yields, reduced chemical inputs; improved farmer and consumer health.

D) Abiotic stress tolerance in GM rice

Water deficiency, degree of temperatures (high or low) and ion toxicity or deficiencies are the major abiotic stress conditions for the plant that reduce growth and result in significant yield losses. Abiotic stresses especially salinity and drought cause for approximately 70% of yield reduction in crops (Acquaah, 2007). Improving the tolerance to abiotic stresses has been one of the major goals in agriculture for long period of time. Manipulation of single genes that affect specific targets (metabolites or proteins) has been the most common strategy for improving abiotic stress tolerance in plants (Peleg *et al.,* 2011; Pardo, 2010; Umezawa *et al.,* 2006).

Drought is an important biotic stress which affects the normal growth and development of plant, result in significant yield reduction. There several genes which encode for different protein involved in Signal transduction and transcription control such as mitogen activated protein (MAP) (Shouet al., 2004), salt oversensitive kinases (Qiu *et al.,* 2002), phospholipases (Thiery *et al.,* 2004) and transcription factors for instance, Heat Shock Factor (HSF) and the C-Repeat-Binding Factor (CBF) /Dehydration Responsive Element Binding Protein (DREB) and ABA-responsive element binding factor/ABA responsive element (ABF/ABRE) (Zhang *et al.,* 2004). These proteins are extensively used to develop transgenic rice plant against various abiotic stresses. DREB factors are indirectly involved in the expression of multiple genes involved in various abiotic stresses like drought, salinity and freezing and it has been used to increase drought tolerance in rice. Recently, it has been reported that the over expression of OsDREB2A significantly enhanced drought and salt tolerance of transgenic rice plants (Cui *et al.,* 2011).

Heat Shock Proteins, molecular chaperones and Late Embryogenesis Abundant Proteins play a significant role plant abiotic stresses. Transgenic plants in Basmati rice with over expression of HSP101 resulted in significant improvement in plant growth recovery after heat stress (Katiyar *et al.,* 2003). Rice plants transformed with HVA1 (*Hordeum vulgaris* abundant protein) gene encoding group 3 LEA proteins showed dehydration tolerance (Chandra Babu *et al.,* 2005).

Amino acids i.e. proline accumulation improved plant performance under salt stress has been reported in a number of studies (Kavi-Kishore *et al.,* 2005). Transgenic plants over expressing Ä1-Pyrolline-5-carboxylate synthetase (P5CS) in rice, showed salt tolerance (Bakshi and Dewan, 2013). The researchers transferred a set of genes which control the expression of trehalose (a non-reducing sugar) into a variety of Indica rice. Transgenic rice plants with increased trehalose level are photo-synthetically efficient and tolerant to photo-oxidative experienced during stress condition (Bakshi and Dewan, 2013).

Introduce C4 photosynthetic pathway into C3 crops is one of the major issues for increasing photosynthetic activity, resulting in better growth and higher yield. In recent years, efforts have been given to engineer C4 photosynthesis into C3 crops (Hibberd *et al.,* 2008; Sage and Zhu, 2011). The expression of genes encoding enzymes such as phosphoenolpyruvate carboxylase (PEPC), the chloroplast pyruvate orthophosphate dikinase (PPDK), and NADP-malic enzyme (NADP-ME) into rice improved photosynthetic rate and yield (Ku *et al.,* 2000; Matsuoka *et al.,* 2001; Jiao *et al.,* 2002).

E) Bio-fortified rice

Bio-fortification is a potentially cost-effective and sustainable way to increase a crop's nutritional value. Evidence thus far has shown that bio-fortification of crops can contribute significantly to reduce inadequate nutrition in countries throughout the world. While it appears this effort will be cost-effective compared to the methods of supplementation or fortification of foods, genetically engineered traits which benefit consumers have not yet moved into commercialization.

a) Golden rice: Rice is generally deficient in vitamin A; around 124 million children worldwide are vitamin A-deficient leading to death and blindness. Mammals make vitamin A from β-carotene, a common carotenoid pigment normally found in plant photosynthetic membranes. The idea to engineer the β-carotene pathway into rice resulted in the development of golden rice' during 1990s. Golden rice introduced in 2000, was genetically engineered to produce pro-vitamin A by Professor Ingo Potrykus, Dr. Peter Beyer & other European scientists (Beyer *et al.,* 2002), and was followed up in 2005 with golden rice 2 for increasing the amount of pro-vitamin A over 20 fold (Dubock, 2014).

b) Engineering higher folate levels in rice endosperm: Folate, also known as vitamin B9 which function to enhance the body's metabolism and promote and Folate, also known as vitamin B9; function to enhance the body's metabolism and promote and restore cellular growth. Storozhenko *et al.* (2007) engineered rice using targeted expression of Arabidopsis GTP-cyclohydrolase I (GTPCHI) and aminodeoxychorismate synthase (ADCS) to increase folate biosynthesis in seeds. The strategy worked best when GTPCHI and ADCS were expressed together from a single locus, resulting in 15- to 100-fold increases in folate levels in different independent transgenic lines.

F) Iron accumulation in transgenic rice with ferritin gene: Iron deficiency is considered to be one of the most widespread micronutrient deficiencies worldwide resulting in anaemia, heart problems, and neurological disorders. Despite the fact that whole grains, vegetables and fruits contain iron, absorption of the micronutrient is poor from these food sources because it is in complex with phytic acid. Since rice is a staple food for over 3 billion people, improving its iron content could help tackle the problem of iron deficiency especially among developing countries (ISAAA Brief 46-2013). Scientists have fortified the level of bioavailable iron in rice seeds using soybean ferritin gene by increasing the expression of nicotianamine synthase (NAS) (Lucca *et al.,* 2001).

G) Developing allergen-free rice

Rice seed proteins are known to be a causative antigen in some patients with food allergy, especially cereal allergy, with clinical symptoms such as eczema and dermatitis. The α- amylase/trypsin inhibitors (14–16 kDa), “-globulin (26 kDa) and β-glyoxalase I (33 kDa) are regarded as major potential allergens of rice seed based on speciûc recognition by serum IgE from allergy patients (Wakasa *et al.,* 2011). Researchers from Japan were successful to reduce the percentage of these three allergens in a mutant in the ‘Koshihikari’ background lacking the 26 kDa allergen (GbN-1) using null mutant in combination with an RNA silencing method.

Future prospects: Engineering of varieties with durable and broad spectrum resistance for disease and insect pest is an ultimate goal for breeding. This will be achieved probably through genetic manipulation of the regulatory mechanisms and signaling processes. Using genomics and proteomics approaches will lead to identification of novel genes that are involved in the defense signaling pathways and subsequent metabolic pathways. These genes will be very useful in the generation of new rice varieties with high level of resistance (probably durable resistance) against multiple diseases and insect pests. Also in the coming future bio-fortified and allergic free rice will be commercialized in world wide. Transgenic approach for imparting abiotic stress tolerance, although at a very low key, is slowly gaining importance. Apart from addition of function, deletion of function by RNAi approach is increasingly becoming popular. With all the GM crops that have been developed and accepted in different countries, many countries are yet to accept and commercialize them. For instance, the herbicide resistant rice Clearfield® was released and commercialized in the US but not in any other country. Similarly, insect resistant *Bt* Cotton and *Bt* Brinjal were once released and even accepted but were again banned for reasons that they are harmful to living organisms including human. Manipulation of crop plants against environmental stresses or abiotic stresses have also been successful by altering different pathways or functions of a system in an organism. Collective contribution of GM rice to sustainability and the potential for the future is enormous. But, hindrances might come from the mass population fearing side effects since they are new, different and unknown to people. Political issues are another concern for the commercialization of GM rice. Thus we can conclude that the future prospect of GM rice will flourish unless it is met by some loop holes. As more and more genetic engineering is being used to achieve breeding objectives, GM rice is now on its way to fields in several countries.

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