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Review Article

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GENETIC BASIS OF STRESS TOLERANCE IN RICE

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Abstract: *Rice (Oryza sativa L.) is an essential diet for almost 50% of the global population. Rice harvests are vulnerable to a variety of living and non-living stresses. Pest insects, fungi, bacteria, viruses, and herbicide toxicity are a few examples of biotic stressors. Drought, cold, and salinity are three abiotic conditions that rice has also been extensively affected. Several genes have been discovered, cloned, and described to counteract these challenges and safeguard rice crops. Transgenic plants are created by successfully introducing the identified genes into rice plants. Rice crop improvement is significantly impacted by genetic engineering. This review article discusses the increased rice quality features tolerating living and non-living stress. This review's goal is to give readers a summary of recent advancements in rice biotechnology research and development.*

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Introduction

Rice was one of the first crops to be domesticated (*Oryza sativa* L.). For thousands of years, it has been raised in China and India. (Poehlman plus Sleper, 1995). Oryza sativa (2n = 24), Most widely farmed classes of rice, is a tropical Asian native. Only in western tropical Africa are the different rice classes grown, *Oryza glaberrima* (2n = 24), which remains native ascending the Niger River's upper valley. Ten identified genome varieties are AA, BB, CC, BBCC, CCDD, EE, FF, GG, HHJJ, and HHKK; 23 species; of Rice are known. The untamed *O. rufipogon*, a perennial plant, and the untamed *O. nivara*, a perennial are close cousins of *O. sativa*. Both weedy species are diploid and have the AA genome. Because of the ongoing population growth, rice must continually improve as a food crop. The following main goals are sought to enhance rice crops using biotechnological methods. Among the characteristics that these crops may have been high yield potential, early maturity, resistance to lodging and shattering, environmental stress tolerance, disease and pest resistance, increased grain quality, and improved nutritional components.

The value of rice to the economy

Apart from Southeast Asia, China, India, Pakistan, Japan, and Korea nearby regions produce rice accounts for 90% of global production (USDA, 2014). The output from Brazil and the United States is most rice outside the Asia (1995; Sleper and Poehlman). Almost half of the globe's population relies mainly on eating sources of rice (FAO, 2008). Oryza is the staple food crop that has a significant transfer from Pakistan. It contributes 0.7% to the GDP, and 3.2% to all agricultural value added. The expected area sown for rice is 2.891 106 ha, while the yield in 2014–2015 was 7.005 106 t. (Ministry of Finance, 2015). In Pakistan, rice is grown under a variety of weather circumstances. In Punjab Province's traditional rice-growing region, basmati rice (Indica) is farmed. Japanese rice grown in Swat is temperate and grows in high-altitude valleys. The majority of Long-grain tropical rice of the IRRI type is cultivated in the southern regions between Baluchistan and Sindh.

Crop transformation in rice fields

Our Globe would 25 percent more rice is required by 2030 to fulfil the anticipated demand for a growing global people (Wani and Sah, 2014). Growing rice on more land is one approach to addressing this problem, although doing so is challenging given the rapid urbanisation and population growth in countries with low development. The alternative is to boost per-hectare production and improve varieties through breeding initiatives using traditional techniques and contemporary biotechnology. Biotechnology promises to increase crop productivity and reduce loss from diverse living and non-living challenges (Mahmood-ur-Rahman et al., 2014b; Ozawa and Takaiwa, 2010; Gelvin, 2010).

Rice that resists insects

Modern agriculture has been transformed by insect-resistant crops, which are now a key component of integrated pest control strategies, reducing the need for insecticides while safeguarding environmental issues and Community health (Brooks and Barfoot, 2013). In the same way, other crops were created, insect-resistant rice plants were around for around 20 years (Fujimoto et al., 1993). Currently, field tests of genetically modified rice plants (Bt rice plants) that express a trait taken by Bt rice are being conducted in several nations (Wang et al. 2014; High et al. 2004; Tu et al. 2000). Several research suggest rice that is BT can diminish brought on via lepidopteran pests inside Asia (High et al., 2004). Using an artificial gene i.e. cry1Ab, transgenic rice turned out to be much more 8 Lepidoptera, as well as stripe-headed stem borer, resistant (*Chilo suppressalis*; SSB) plus Shu et al. state that stem borer in yellow (2000) (YSB; incertulas of the Scirpophaga). Also, dual strains of Bt Oryza plantations exhibited significant lepidopteran resistance. Pests in outdoor settings (Deka et al., 2010; Wang et al. 2014; Kumar et al. 2008). Table 1 reviews significant turning points in the emergence of rice plant life that remains insect-resistant.

At a field in China, insect-resistant hybrid rice Testing revealed that plants were extremely resistant to the YSB (Tu et al., 2000; Deka and Barthakur, 2010; Chen et al., 2011). The rice leaf folder (RLF; *Cnaphalocrocis medinalis*). Moreover, insect-resistant Bt rice has been developed in Pakistan and the Mediterranean. (Mahmood-ur-Rahman et al ., 2007; Breitler et al., 2004). Current studies conducted in mutual areas revealed great resistance to the YSB and RLF, the target insects (Breitler et al. 2004; Bashir et al., 2005; Mahmood-ur-Rahman et al. 2007, 2012, 2013, 2014a, 2014b; Tabashnik et al., 2009) (Table 2). The target insects weren't naturally introduced to rice plants (Figures 1A–1C), and the intensity of their attack was quantified. India has also created certain transgenic rice lines and types resistant to YSB (Ramesh et al. 2004). In China, transgenic rice plants have been created in both fields and laboratories experiments have been conducted or done to see how effective they are (Li, 2013; Li et al. 2014; Wang et al. 2012). It particularly effective in creating long-lasting resistance against insect pests by pyramiding numerous genes against a certain pest or a variety of insects. Cry1Ab or Cry1Ac have been studied to pyramid with either.

Table 1. Enhancing rice genetically to withstand insects

genes	Aims	Reference
cry1Ab and cry1Ac	SSB, YSB, and SSB**	Su et al., (2000)
cry1Aa and cry1Ab		Breitler et al., (2004)
cry1Ab or cry1Ac	SSB	Ramesh et al., (2004)
cry1Ab	RLF and YSB ***	
cry1Ab	Sheath blight, bacterial blight, and YSB	Cotsaftis et al., (2002)
cry, Xa21, or RC7	Insects that are homopteran, coleopteran, and lepidopteran	Bashir et al., (2005)
gna or cry1Ac	Wheat weevil	Datta et al., (2003)
Itr1	RLF and YSB	Nagadhara et al., (2003)
cry1Ac or cry2A	Bug resistance	Alfonso-Rubi et al., (2003)
Bt or CpT1	Bug opposition	Mahmood-ur-Rahman et al., (2007)
Bacillus thuringiensis, lectins from plants, enzymes, or protease inhibitors	Bug opposition	Rong et al., (2007)
cry2Aa	Bug opposition	Deka and Barthakur, (2010)
cry1Ab	SSB, YSB, and SSB**	Wang et al., (2012)

Table # 2. GM Rice evaluation in the Fields

genes	Characteristics	Sites	Reference
cry1Ab or cry1Ac	resist insects	China	Tu et al., (2000)
cry1Ab	resist insects	China	Su et al., (2000)
cry1Ac or cry2A	resist insects	Pakistan	Bashir et al., (2005)
cry1Aa or cry1B		Spain	Breitler et al., (2004)
Cry2A	resist insects	China	Chen et al., (2005)
cry1Ac or cry2A	resist insects	Pakistan	(Mahmood-ur-Rahman et al., 2007, 2012, 2014a)s
cry1Ac or CpT1	Resist insects	China	Han et al., (2006)
cry1Ab	Resist insects	China	Wang et al., (2014)
Xa21	Resist insects	China	Tu et al., (2000)
bar	blight resistant to bacteria	United states of America	Oard et al., (2000)
bar	Drug-resistant weeds	Spain	Messeguer et al., (2004)
bar	Drug-resistant weeds	United states of America	Zhang et al., (2004)

For enhanced and long-lasting resistance in Bt rice, use cry2A or cry9C. Cry1Ab and Cry1Ac have the same binding site in insects like SSB and YSB and may be particularly successful at pyramiding genes (Alcantara et al., 2004). Increased lectin resistance for the variety was achieved by combining Cry genes with the snowdrop (Galanthus nivalis) lectin gene i.e insects, sucking included insects (Ramesh et al., 2004). Insect pests that suckers have no effect from the Bt genes (Bernal et al., 2002). To create a long-lasting resistance, it's crucial to stack additional insecticidal genes and cry genes. Plants may include proteins that prevent ribosomes from forming, lectins, or protease inhibitors that can be used to produce these genes for non-Bt insect resistance (Sharma et al., 2003). a gene for lectin (Galanthus nivalis agglutinin) has been extensively utilized to create rice with built-in resistance to insects of the Pest species belong to the homopteran, lepidopteran, and coleopteran orders (Nagadhara et al., 2003). Researchers have created and field-tested transgenic rice strains that generate proteinase inhibitors (Mochizuki et al 1999). A Commercial use using genetically engineered rice may benefit from recent advancements such a transgenic expression that is tissue-specific and inducible, pyramiding of many sets of genes greater spectrum delays in the emergence of insect pests' resistant strains and measures of protection (Kumar et al., 2008). Lectins and Gna (Lopez et al., 2002) is less effective than anti-protease agents (Hernandez et al., 2003). It may be possible to create insect-resistant rice using lectins and protease inhibitors that are more efficient against sucking insects (Kumar et al., 2008).

Fungus-Resistive Rice

Given that this yield is liable for the variety to infections, among them are viruses, bacteria, and fungus, genetic modification of fungal resistance of rice is urgently needed (Gust and others, 2010, Miah et al., 2013, Sattari et al., 2014). Many genes were found to provide resistance to several fungus species, identified, replicated, then transformed to rice plants. Recently, the Pi-ta gene was cloned, it was discovered to exhibit high resistance to rice disease i.e Blast (Delteil et al., 2010; Dai et al., 2010). Study and mapping of indigenous resistance to sheath blight (Liu et al., 2009). Also, genetic indicators were discovered through cross-breeding between susceptible/non-transgenic and transgenic types (Liu et al., 2009). Generations of Asian rice with the PR-3 rice chitinase gene were discovered to resist hermetic blight (Datta et al., 2003). The group of defense- similar Genes includes Rir1b Gene. It was just discovered. and described in the Grains (Mauch et al., 2000). Rir1b-containing Gene-modified Rice was more resistant to Rice Blast (Li et al. 2009). Also, numerous proteins were discovered to be helpful for candidates to give rice plants resistance against various fungal species, which help to facilitate pathogen assault. Examples include the selenium-binding protein homolog (Sawada & al., 2004), the puroindoline proteins (Krishnamurthy et al., 2001), the lipid transfer protein (Guiderdoni et al., 2002), and the rice homolog of maize HC-toxin reductase (Uchimiya et al., 2001; Higa et al., 2003).

Bacteria-resistant rice

By modifying the endogenous gene Xa21, transgenic rice blight-resistant strains that resist germs were created (Song et al., 1995). Several Rice cultivars have Xa21 introduced through both genetic modification and traditional breeding methods ((Mohanty and Tyagi, 2000). There have been tests on Xa21-transgenic plants in the field with encouraging outcomes (Tu et al., 2000). The top option for creating bacterial blight resistance so far was discovered to be this gene. Additionally, it was stated that the gene and other genes could give several forms of stress tolerance (Datta et al., 2003). The rice Gene Xa 26, which expresses the same protein as similar effects in transgenic plants to those in Xa21-expressing plants, was also found to be resistant (Zhang, 2009; Sun et al., 2004). To create rice that is resistant to germs, certain additional genes have also been altered (Zhou et al., 2011). A class of the Genes called cecropins has antibacterial properties. In Cecropia moth hemolymph, they express peptides. They have transformed and have successfully expressed themselves in plants (Huang et al., 1997). AP1, a ferredoxin-like protein produced by transgenic rice plants, displayed ability to tolerate X. *oryzae* (Tang et al., 2001). Moreover, Burkholderia plantarii resistance has been induced in rice. Due to decreased pathogen damage, rice plants that express Xa21 in the field exhibit a considerable boost in production (Tu et al., 2000). For long-lasting resistance to bacterial infections in rice, the commercial release of the promising candidate gene Xa21 should benefit all farmers Kumar et al. (2008)

Virus-resistant rice

For many years, yield loss brought on by viruses has been a major issue worldwide. In particular, the rice dwarf virus (RDV) and the rice stripe virus (RSV), which led to significant production losses during 1960 (2010) (Toriyama),are now more likely to cause damage. Insecticides can be rice fields may be managed using the method used to control vector insects, however their high cost and environmental risk are the main barriers. One of the best ways to shield rice plants against viral infection is through the evolution of rice virus resistance genetically or the insects that serve as their insect vectors. Researchers created and assessed rice plants resistant to RSV and RDV (Sasaya et al., 2013; Shimizu et al., 2009; Xiong et al., 2009). The viral rice illness known as Rice tungro is quite dangerous. RTBV (rice tungro bacilliform virus) and RTSV (rice tungro spherical virus) are two viruses. —are responsible for its development (RTSV). The green leafhopper (*Nephotettix virescens*) acts as RTSV's vector and aids in the spread of the disease. Using the coat, rice plants have changed protein-mediated defence mechanisms

(Huet et al. in 1999). Developed transgenic rice plants with the RTSV replicase gene. The transgenic plants demonstrated a minor amount of RTSV resistance.

Rice resistance to herbicide

Agrochemical resistance is a crucial agronomic feature that has been effectively employed for many years to eliminate weeds. The EPSPS and bar genes are only two of the many genes being exploited to create herbicide-tolerant plants. The EPSPS gene was acquired from Agrobacterium strain CP4 and detoxifies glyphosate herbicides, while the bar gene was taken from *Streptomyces hygroscopicus*, which detoxifies the herbicide glufosinate (Kumar et al., 2008). In the early days of rice transformation research, herbicide-resistant GM rice plants carrying the bar gene were created; these plants are currently undergoing field testing (Tyagi and Mohanty, 2000; Oard et al., 2000). It has taken a lot of labour to find other gene sources that could be exploited to give transgenic rice long-lasting resistance to herbicides. One such instance is the protoporphyrinogen oxidase produced by the bacterium Bacillus subtilis, which rice plants effectively use to develop resistance to the oxyfluorfen herbicide (Jung et al., 2004). Another illustration is people's Cytochrome P450s, which, when overexpressed in rice led to inconsistent herbicide reactions (Kawahigashi and co., 2003).

Rice Resistant to abiotic stress

Droughts, extreme heat or cold, salinity, submersion, and oxidative stress are abiotic factors that severely lower crop productivity. These pressures have been documented to cause crop loss of more than 50% internationally (Iqbal et al. 2013; Li et al., 2016; Bray et al., 2000). It frequently interacts with one another and result in similar cellular and physiological harm. Moreover, they stimulate similar mechanisms for cell signaling (Qin et al., 2011); Nakashima et al. (2009). Several proteins, antioxidants, and suitable solutes are created in response to stressful situations. Many agricultural plants have been created by overexpressing the genes for these chemicals, and they have been tested in both the lab and the field for many different abiotic stresses (Luo et al. 2010). The worst elements that reduce rice crop output are tolerance to water scarcity and salt stress. One method to improve crop plants' ability to withstand abiotic stress is GM technology (Flowers, 2004). Creating transgenic plants with various genes that produce drought and/or salinity tolerance in multiple plants has helped crop species like rice (Tyagi and Mohanty, 2000; Iqbal et al., 2013). (Table 3). Moreover, many new genes have been discovered and identified in model plants that confer tolerance to salt and drought stress (reviewed by Flowers, 2004; Zhang et al., 2004).

Using the chloroplastic glutamine synthase (GS2) gene, Hoshida et al. (2000) successfully created transgenic rice plants. Strong salt and freezing stress tolerance and improved photorespiration abilities have been demonstrated in transgenic plants with high GS2 levels (Hoshida et al., 2000). OsMAPK5, a stress-sensitive MAPK gene that responds to ABA and other biotic and abiotic stimuli in rice, was found and described by Xiong and Yang in 2003. OsMAPK5 overexpression makes plants more resistant to salt, cold, and drought stress (Xiong and Yang, 2003; Osakabe et al., 2014; Savchenko et al., 2014)

Table 3. Oryza sativa genes that can withstand abiotic stress

S. No.	genes	Purpose	Origin	Features of transgenic plants	reference
1.	GS2	glucose synthesis	Oryza sativa	tolerance of the effects of cold and salt	Hoshida et al., (2000)
2.	OsCDPK7	PTKs that is calcium-dependent	Rice	tolerant of the stresses of drought and salinity	Saijo et al., (2000)
3.	OsMAPK5	A Mitogen-activated protein	Oryza sativa		Yang and Xiong (2003)
4.	Adc, Samdc		Oats		
5.	HVA1	Late embryogenesis abundant proteins polyamine biosynthesis	Barley and Wheat	tolerance of the stresses of drought and salinity	Babu et al. (2004); Capell et al. (2004)
6.	OtsA	Anabolism of trehalose	Bacteria	tolerance of the stresses of dehydration and salt	Jung et al., (2003)
7.	p5cs	prostaglandin synthesis	dew gram	Salt, drought, and cold stress resistance	Hur et al., (2004); Rahman et al (2001)

8.	pdc1, adc	(ODC) of pyruvate	Oryza sativa	Transgene expression in response to stress	Ariizumi et al., (2002)
9.	AGPAT, SGPAT	Formulation of lipids	Spinacia oleracea	tolerance for submersion	Matsumura et al. (2003); Yamanouchi et al (2002)
10.	Cat	Catalase	Triticum	enhanced photosynthetic efficiency at cold temperatures	Hoshida et al., (2000)
11.	spl7	heat stress transcription factor	Oryza sativa	Cold-tolerant	Saijo et al., (2000)

In response to abiotic stress, dehydration-responsive elements (DREs) control the expression of numerous genes (Nakashima et al., 2014; Wani and Sah, 2014). OsDREB1A, OsDREB1B, OsDREB1C, OsDREB1D, and OsDREB2A are the five rice DREB homologs of *Arabidopsis* that were discovered and characterized by Dubouzet et al (2003). Several OsDREB genes were overexpressed in transgenic rice plants while regulated by various promoter combinations. They asserted that OsDREB1A was especially useful in generating transgenic dicot and monocot plants that were more resistant to the impacts of cold, salt, and/or drought (Nawaz et al., 2014; Wang et al., 2007).

The ACS gene causes rice plants' resistance to submersion. The vascular bundles of juvenile stems and leaf sheaths showed greater mRNA levels when the plant was partially immersed. The same outcomes were also seen in rice when the YK1 gene was overexpressed (Uchimiya et al., 2002). Spl7, a transcription factor, was identified and cloned in rice plants. In spl7 mutants, its overexpression reduced the development of leaf spots brought on by high temperatures (Yamanouchi et al., 2002). Furthermore, heat shock proteins or oxidative stress-tolerance enzymes have been overexpressed in rice plants to produce heat-tolerant rice plants (Murakami et al., 2004; Kouril et al., 2003)

Conclusion

Regarding global food security and sustainable agricultural methods, the genetic underpinnings of rice's ability to withstand biotic and abiotic stress are a required field of study. One of the major food crops on the planet, rice gives millions of people a significant source of calories and nourishment. Unfortunately, rice crops are vulnerable to several biotic and abiotic stressors, which can seriously reduce productivity and jeopardize food security. Because of the importance of rice economically and the difficulties brought on by biotic and abiotic stressors, creative solutions are needed. The production of rice cultivars with improved stress tolerance is made possible through genetic engineering, which offers a viable strategy for overcoming these difficulties. The production of rice variants with increased stress tolerance has been made possible through the genetic engineering of rice crops. A few examples of the genetic alterations created to address the problems facing the rice business are insect resistance rice, fungus resistance rice, bacterium resistance rice, virus resistance rice, and herbicide tolerance rice. These improvements may boost crop yields and enhance food security in areas where rice is a staple crop. The transmission of stress-induced alterations also complicates the genetic foundation for stress tolerance in rice through generations and our emerging understanding of epigenetic modifications. This opens up new opportunities for creating rice types more resistant to stress. To make sure that the potential advantages of genetic engineering have been achieved while avoiding the hazards. It is necessary to approach genetic engineering research cautiously, focusing on safety evaluations and regulatory frameworks. It is crucial to weigh the possible advantages against the potential drawbacks to make new genetic tools and technologies safe for the environment and people's health. Therefore, it is essential to continue studying the genetic underpinnings of rice's ability to withstand biotic and abiotic stress to promote sustainable agricultural methods, ensure global food security, and solve issues affecting the rice sector. The global rice business might change if more robust, high-yielding, and nutrient-dense rice varieties are created, allowing farmers to produce more food with fewer resources and maintaining food security for millions of people.

Conflict of interest

The authors declared absence of conflict of interest.

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