*INT. J. BIOL. BIOTECH.*, 16 (1): 27-36, 2019.

# ROLE OF BIOTECHNOLOGY FOR THE IMPROVEMENT OF STRESS TOLERANCE IN PLANTS

**Arif Malik[1], Samra Javed[2], *Qurban Ali[1], Maida Mehmood[1], Muzammal Mateen Azhar[1], Ali Tahir[1], Kausar Malik[3] and Ayesha Zahid[1]**

[1]*Institute of Molecular Biology and Biotechnology, University of Lahore, Pakistan*
[2]*Department of Biotechnology, Kinnaird College for Women, Lahore, Pakistan*
[3]*Centre of Excellence in Molecular Biology, University of the Punjab Lahore, Pakistan*
*Corresponding Author: email: saim1692@gmail.com

**ABSTRACT**

The field of biotechnology has extraordinarily influence on science, law, the administrative condition social insurance, and business. As the starting of agriculture, people have been manipulating crops to improve the yield and quantity. Product yields throughout the world are essentially diminished by the activity of herbivorous insects, pathogens and parasites. Natural environmental stresses make this circumstance significantly worse. Abiotic stresses are the important factors for crop development and improvement, causing massive yield losses over the worldwide. Many mechanisms have been utilized for engineering abiotic stress tolerance in model and other crop plants by means of established biotechnological and/or breeding techniques. The use of genetic engineering technology improvement to particular characteristics is then discussed about, including input aspects identifying with control production (herbicide and insects resistance, protection from pathogens and abiotic stresses). Crop improvement has been improved the many years by means of conventional plant breeding strategies or over different physical, chemical compound (e.g., gamma radiation, ethyl methane sulfonate) and other biological techniques (e.g., T-DNA, transposon insertion) primary to point mutations, rearrangement, duplication and insertion. Zinc finger nucleases have been effectively utilized in genome modification of different plants including tobacco, maize, soybean, and so on. The understanding of molecular basis of plant reaction to these natural environments or stresses has been an important focal point of research in the past decades. Genetically modified organisms are being utilized to lessen the yield loss because of different stresses (biotic and abiotic) and are being utilized broadly for value increase in food crops by improvement with quality proteins, vitamins, zinc, carotenoids, anthocyanin, iron and many more. Incorporation of modern biotechnology, with regular traditional practices in a sustainable way, can fulfill the objective of achieving food security for present and as well as in future.

**Keywords**: biotechnology, agriculture, biotic, abiotic stress, T-DNA, transposon insertion

## INTRODUCTION

During the past two decades, the word ‘biotechnology’ has received enormous significance and importance which is just unprecedented. The possibilities and probability of outcomes after this sort of consideration to biotechnology might be because of its indefinite prospective to serve and to profit the humankind. Biotechnology has touched our lives in all fields, for example, animal life, health, and food. The word 'biotechnology' has been derivative of two terms of science, i.e., the one is Biology’ and later is ‘Technology’. It is fascinating to learn and see how and when biotechnology actually developed. In 1919 for the first time the word biotechnology was used by a Hungarian Engineer, Karl Erkey (Fári and Kralovánszky, 2006). According to a definition of biotechnology it is, “Application of biological science and the principles of engineering to make novel products from raw materials of biological origin, such as, food or vaccines (Ezejiofor *et al*., 2014; Marsh, 2003; Verma *et al*., 2011). The field of biotechnology has extraordinarily influence on science, law, the administrative condition social insurance, and business. More than 260 novel products of biotechnology were approved for above 230 indications. In 2013 global sales of such products exceeded $175 billion and have maintained a lively life sciences division that incorporates in excess of 4,600 biotech organizations overall (Evens and Kaitin, 2015). In the 21st century many see biotechnology as a significant role in improving the quality of life. , biotechnology is closely tied to scientific knowledge and science. In every aspect, biotechnology promotes a certain vision of life, one in which some things are seen too and to be encouraged (O’Mathúna, 2007; Sasson, 2005). As the starting of agriculture, people have been manipulating crops to improve the yield and quantity.

The seed producers have advanced the new wheat hybrids and normally grown corn nowadays via conventional breeding. Then, scientists began starting the genetic engineering techniques in 1980’s-1990, to improve crop quantity and quality (Bud, 2002; Ewing, 2001; Harlander, 2002). Tissue culture techniques and genetic engineering frame the premise of plant biotechnology can add to the greater part of the yields change the stages (Huang *et al*., 2002; Pauls, 1995). Transgenesis is a significant process to traditional plant breeding, in that it permits the focused on control of particular characters utilizing qualities from a scope of sources. The current status of crop transformation comprising the methods of, the selection of transformed plants, transfer of gene and control of its expression is studied (Gianessi *et al*., 2002; Kumar *et al*., 2009). The use of genetic engineering technology improvement to particular characteristics is then discussed about, including input aspects identifying with control production (herbicide and insects resistance, protection from pathogens and abiotic stresses) (Rosse *et al*., 1991; Slater *et al*., 2003). In this review, the part of biotechnology and its achievements, prospects and difficulties in growing stress tolerant plants are studied.

## GENETIC ENGINEERING FOR CROP IMPROVEMENT

Those plants that have been genetically altered by using recombinant DNA technology are called transgenic plants. This might be to indicate a quality that isn't natural to the plant or to alter endogenous genes. Product yields throughout the world are essentially diminished by the activity of herbivorous insects, pathogens and parasites. Example of two genetically modified crops grown here are the insects free safe by expressing the BT genes from the bacterium *Bacillus thuringiensis* and virus free genetically modified papaya (Otani *et al*., 1998; Puspito *et al*., 2015; Qamar *et al*., 2015; Tu *et al*., 1998). The principal of the crops has been specifically effective; in USA, for instance, insect free genetically modified maize is become over a territory of 10.6 million hectares and it includes 35% of all maize (Non genetically modified and genetically modified) developed in nation. At the level of research laboratory, resistance has similarly been developed to fungal and bacterial pathogens. The main reasons for plant loss throughout the protein encoded by the gene will express a specific characteristic or trademark to the plant (Mantell *et al*., 1985; Stafford *et al*., 1986).

The tools can be used in a numerous methods, such as to develop resistance to abiotic stresses, for example temperature extremes or saltiness drought, and other stresses, like insects and pathogens, that would ordinarily demonstrate unfavorable to crop development and its survival. In 2007, for twelfth sequential year, global territory of biotech plants implanted kept on expanding, by 12% of development rate crosswise over the 23 nations. Guide crops are soybean and maize, despite the fact that cotton, canola and rice are likewise on the expansion. Though GM plants grown in the EU add up to just a couple of thousand hectares, that is most likely an impression of European resistance to this revolution the worldwide are abiotic stresses (Aaliya *et al*., 2016; Qamar *et al*., 2015), especially saltiness, drought, and high temperature. After this, these losses will increase as water resources decline and desertification intensifies. Saltiness and drought are depending upon to cause severe salinization of each distinct arable land by 2050, requiring the execution of new technologies to ensure the crop survival. Some study by Key and his colleagues indicating the expression of an enzyme in GM maize which stimulates an oxidative signal cascade confers saltiness, heat and temperature extremes tolerance (Wang *et al*., 2000; Wasternack, 2007). Genetic engineering technology offers an approach to ease a portion of such issues by developing the crops to express the extra yields that can battle the lack of healthy sustenance. Golden Rice Project' is a significant example of the prospective of this technology. Due to insufficiency of vitamin A nearly 2 million children every year are dead throughout the world. Vitamin A can be synthesized from the precursor β-carotene that is regularly found in numerous crops however not in cereal grains. There are various approaches for the development of GM crops. The most generally utilized are the *Agrobacterium tumefaciens* that is normally capable to transfer its DNA to plants, and the other is 'gene gun, in which shoots minute particles covered with DNA into the plant cell (Key *et al*., 2008; Qamar *et al*., 2015).

## DIFFERENT PLANT STRESSES

Natural environmental stresses make this circumstance significantly graver. Regardless of the induction of a few resistance systems, sensitive plants frequently fail to make due under natural excesses. Different mechanical methodologies are basic. Traditional breeding strategies have a constrained prospective to enhance genomes of plant against environmental stresses. Genetic engineering has contributed massively to the advancement of GM assortments of various plants, for example, maize, rice, cotton, and canola and so on. The identification of genes against the stress and the consequent introgression or overexpression inside sensitive crop species are currently being broadly done by plant researchers (Ahanger *et al*., 2017; Altman, 2003). A good situation for single plant genotype might not be for other plant, and every outside factor abiotic or biotic, may increase a stress or challenge to the crop contingent upon the plants genetic makeup and adaptive reaction (Pereira, 2016; Umezawa *et al*., 2006; Vinocur and Altman, 2005). Abiotic stresses are the significant requirement on crop development and improvement, causing massive yield losses over the worldwide. Plants have distinctive features to protect themselves contrary to these difficult unfavorable stresses responsive (Vinocur and Altman, 2005).

They adjust their phenotypes upon the modifications in physiological, molecular, biochemical, and genetic information, along these lines making them tolerant against these stresses. This is of vital significance to regulate the stress tolerant features of an assorted scope of genotypes of plant species and incorporate the characteristics for crop modification. Stress-tolerant characteristics can be distinguished by directing genome wide analysis of genotypes over the exceedingly progressive functional and structural genomics approach (Bhatnagar-Mathur *et al*., 2008; Mohanta *et al*., 2017; Shriram *et al*., 2016). A few cases of various stress combinations that are required to emerge because of environmental variation and their effect on plants is given in Complementary Concurrently happening drought and heat stretch stances as the most apparent stress combination. Similarly, plants developing in arid and semi-arid areas regularly confront a combination of saltiness and heat stretch (Song and Zhang, 2017; Wani *et al*., 2017). Grapes growing in midditerean areas considered by a mainland atmosphere, confront a blend of dryness and cold stress which influences their yield, winter wheat is additionally known to encounter a combination of ozone and cold stress which decreases its frost resilience. Similarly, saltiness joined with ozone stretch decreases yields of chickpea and rice (Pandey *et al*., 2017a; Wani *et al*., 2016).

## COLD STRESS

Plants have built up unique mechanism to adjust to challenging natural conditions, and flourish in regions characterized by abiotic stresses, for example, temperature extremes. Species-particular contrasts in temperature resistance have developed in plants that involve distinctive geographic zones (Kasuga *et al*., 1999; Shinozaki and Yamaguchi-Shinozaki, 1996). Yearly yields from mild atmospheres, for example, wheat, oats, grain or pea, show a specific level of basal freezing resistance, which they can additionally increment by using complex signaling events. Interestingly, most species from subtropical or tropical atmospheres, for example, maize, rice or tomato, endure damage at chilling temperature (Kilian *et al*., 2007; Nakashima and Yamaguchi-Shinozaki, 2006; Wang *et al*., 2000). Thus, chilling and freezing stress constitute probably the most serious abiotic factors that lessen crop yield. Since consistent and high quality crop productivity are basic for sustenance security, a comprehension of the molecular modes that support cold stress obstruction is fundamental to furthermore optimize agricultural and horticultural harvest breeding and generation (Eremina *et al*., 2016; Sanghera *et al*., 2011).

## TEMPERATURE STRESS

The effect of high temperature on higher plants is fundamentally on photosynthetic functions. The heat resistance bound of leaves of higher plants concurs with the warm sensitivity of essential photochemical responses occurring in the membrane system of thylakoid. Tolerance limits differ between genotypes, but on the other hand are liable to acclimation (Downs *et al*., 2000; Nover *et al*., 2001). Long term acclimations can be superimposed upon quick versatile change of the warm dependability, occurring in the time scope of a couple of hours. Furthermore, irreversible impacts, high temperature may likewise cause vast, reversible consequences for the rate of photosynthesis. A few studies of photosynthetic gas exchange and chlorophyll fluorescence, intended to inspect the vigorous harmony between photosynthetic carbon metabolism and light responses during consistent state photosynthesis with leaves of cotton plants at various temperatures (Liu and Huang, 2000; Regnier and Kelley, 1981; Weis and Berry, 1988).

## SALT STRESS

Plants are results of eons of development from primeval living life forms in light of abiotic and biotic ecological variations. Between the abiotic dynamics that have formed and keep molding plant advancement, water accessibility is the utmost vital. Water stress in its extensive sense includes together dryness and saltiness. Since cell signaling controls plant reactions and adjustments that is most likely not an embellishment to express that water stress signaling has in extensive part molded the plant life on soil (Bohnert and Jensen, 1996; Pardo, 2010; Wang *et al*., 2000). Drought and salt stress, both with low temperature, are the significant issues for horticulture on the grounds that these unfavorable ecological variables keep plants from understanding their complete genetic potential. Salt stress besets agriculture in numerous parts of the world, especially flooded land. Contrasted with salt stress, the issue of drought is much more inescapable and economically destructive. In some case, studies on water stress signaling have concentrated on salt stress fundamentally in light of the fact that plant reactions to salt and drought are firmly associated and the mechanisms cover despite the fact that the significance of drought and salt stress signaling was perceived long back, some of molecular components were identified as of not long ago. In that capacity, drought and salt stress signaling was assessed just as a major aspect of drought and salt stress resistance, and it has not been assessed as a different issue in this series (Guo *et al*., 2009; Mohanty *et al*., 2002; Zhu, 2002). Molecular analysis of particular genes conferring stress tolerance from tolerant yield increases have brought about the guide based disruption of genes for submergence resilience and salt tolerance in rice, among several others. Salt resistance in rice, and furthermore prompted the distinguishing resistant from maize of the main drought tolerant gene. The variety inside the maize drought tolerance gene is especially intriguing on the grounds that the drought sensitive allele comprises a transposon insert in the promoter that is involved with epigenetic mechanism of the gene that contrasts in circulation among mild and tropical maize (Kumar *et al*., 2010; Pereira, 2016).

## DROUGHT STRESS

Drought stress is the most predominant ecological factor constraining harvest efficiency, and worldwide environmental change is expanding the recurrence of serious drought conditions. The sheer diversity of plant species developed crosswise over climatic areas that incorporate extraordinary dry conditions recommends that, in nature, plants have advanced to persist drought stress with a variety of morphological, physiological and biochemical variations (Kasuga *et al*., 1999; Shinozaki and Yamaguchi-Shinozaki, 1996). 'Drought Resistance ' is a more extensive term related to plant species with adaptive mechanisms that allow them to get away, maintain a strategic distance from, or endure drought pressure. 'Drought escape' is the capability of plant species to finish its life cycle before the beginning of dry season. Consequently, plants don't encounter drought stress, as they can regulate their vegetative and regenerative development as indicated by water accessibility, basically through two unique systems: fast phonological improvement and development plasticity (Hussain *et al*., 2011; Shinozaki and Yamaguchi-Shinozaki, 2007; Taji *et al*., 2002). 'Drought avoidance is the capability of plants to keep up (moderately) higher tissue water content regardless of decreased water content in the soil. This is accomplished through an assortment of unique mechanisms including the minimization of water loss and improvement of water take-up .Water spenders accomplish higher tissue water status by keeping up the water take-up through expanded rooting, hydraulic conductance, and so forth under drought stress. Drought tolerance is the capability of plants to bear low tissue water content through adaptive features (Basu *et al*., 2016; Blum and Ebercon, 1981; Yoshida *et al*., 2010).

## MECHANISMS FOR ABIOTIC STRESSES

Throughout RNA sequencing study demonstrates that exogenous melatonin treatment gave enhanced salt, drought, and cold stress resistances in grass (Bermuda) through tweak of 3933 genes (2361 up-regulated and 1572 down-regulated). Melatonin is an important hormone which is similarly originates to play vital role in the development of plant advancement and abiotic stress reactions (DAI *et al*., 2007; Shi *et al*., 2015; Shi *et al*., 2014). Exogenous melatonin treatment lessened reactive oxygen species burst and cell damage incited by abiotic stress in Bermuda grass. This was predictable with transcriptomic data which demonstrated that redox-related genes were improved. Also, pathway and GO term improvement analysis demonstrated that 8 pathways were over-represented to after melatonin pre-treatment, including nitrogen, transport, hormone carbohydrate metabolism, TCA alteration metal control, redox, and other secondary metabolism. Remarkably,, a few key genes that are involved with ABA (RCAR/PYR/PYL, SnRK2, and NCED3) and JA (JAZs) signaling were essentially changed after melatonin pre-treatment, which may be added to expanded abiotic stress tolerance in plants. Proteomics and metabolomics techniques have been effectively used to distinguish omic level changes amid Bermuda grass stress conditions. Under water shortage condition, 32 proteins had increments in the abundance and 22 proteins showed reduces in the abundance, which were principally associated with metabolism, energy, cell development/division, and protein combination and stress resistance (Chan and Shi, 2015; Hu *et al*., 2016; Krasensky and Jonak, 2012).

In some analysis, chilling treatment balanced the abundance variations of 28 proteins and altogether 51 proteins were regulated by $CaCl_2$ treatment. Moreover, 39 proteins with essentially different abundance after drought stress treatment in leaves and stems of Yukon and Tifgreen plants. To additionally recognize up regulated changes in Bermuda grass upon stress treatment, macroarray analysis was performed and 189 drought responsive entrant genes were distinguished, out of which 120 were up-regulated and 69 were down-controlled (Hussain *et al*., 2011; Jiménez Bremont *et al*., 2013; Kasuga *et al*., 1999). Analysis of functional annotation showed that unregulated genes were predominantly involved with proline biosynthesis, protein repair frameworks, signal transduction pathways, , and removal of poisons , whereas down controlled genes were for the most part identified with fundamental plant metabolism, for example, photosynthesis and glycolysis (Chan and Shi, 2015; Ewing, 2001). The future of yield change through genetic modification might be refined in three important stages. To start with, numerous more loci associated with the trait of ecological alteration should be recognized. Model plants such as Arabidopsis and rice and other tolerant relatives will be fundamental for this procedure for a considerable length of time to come. Second, the suitable alleles for the main loci should be recognized (Bohnert and Jensen, 1996). Wild relatives of every yield will be fundamental for this. This will probably involve different gene combinations, likely imitating more than one of the four physiological procedures.

To distinguish the genes that are intricate with four important regions of osmotic resistance physiology, there has been serious research exertion for the most recent period correspondent with the accessibility of the main molecular genetic techniques acquainted with the plant science community to a great extent by the selection of Arabidopsis as a flexible plant modal system (Krasensky and Jonak, 2012; Kumar *et al*., 2009; Liu and Huang, 2000). With the utilization of numerous technologies for the discovery of stress resilience genes and their suitable alleles, transgenic ways to deal with enhancing stress resistance in plants surprisingly parallels breeding standards with an extremely extended germplasm base and will succeed in the long run (Mohanta *et al*., 2017; Pereira, 2016). The primary genetic methodologies utilizing this plant and its challenging tools were affected significantly by the transcription control model on the grounds that transcription factors and, therefore, other signal segments associated with transcription factors have historic significance emerging from the advance of considerate the gene to organism model and furthermore on the grounds that particular analyses demonstrating evolution in common and plant domestication, specifically, have obviously been impacted all the further drastically by changes in transcription factors or alterations in gene promoters than by mutations in other loci. Today we comprehend through numerous genetic analyses that transcriptional control is significant to phenotype appearance however that numerous other molecular components and procedures play main role in various stresses (Bressan *et al*., 2009; Pérez-Clemente *et al*., 2013; Regnier and Kelley, 1981).

## RECENT TECHNOLOGY FOR CROP IMPROVEMENT

Crop improvement has been improved the many years by means of conventional plant breeding strategies or over different physical, chemical compound (e.g., gamma radiation, ethyl methane sulfonate) and other biological techniques (e.g., T-DNA, transposon insertion) primary to point mutations, rearrangement, duplication and insertion. Introduction of site-specific nucleases featured the significance of site directed mutagenesis over random mutagenesis (Chen and Arnold, 1993; Sawano and Miyawaki, 2000; Zhou *et al*., 1991). Random mutagenesis has additionally its own rundown of limitations as well (Ansai *et al*., 2013; Mahfouz *et al*., 2011). It brings numerous unwanted improvements and changes, which are costly and extremely difficult to screen. Gene editing technique utilizes engineered site specific nucleases to remove, replace or insert a DNA sequence. Improvement of the engineered endonucleases/mega nucleases, ZFNs (zinc finger nucleases) (Geurts *et al*., 2009; Urnov *et al*., 2005), TALENs (transcription activator-like effector nucleases) (Lei *et al*., 2012; Moore *et al*., 2012) and type II CRISPR (clustered regularly interspaced short palindromic repeat)/CRISPR-related protein Cas9 made ready for single nucleotide excision mechanism for plant improvement. These genome-editing techniques utilize programmable nucleases to increase the specificity of the objective locus (Sternberg and Doudna, 2015; Zalatan *et al*., 2015).

Zinc finger nucleases have been effectively utilized in genome modification of different plants including tobacco, maize, soybean, and so on. Analyses on maize wheat and sorghum (provided a tremendous basis to the utilization of CRISPR in genome modification (Arora and Narula, 2017). Various abiotic stresses, for example, drought, saltiness, and heat and temperature extremes are the main limitations to agricultural production. The understanding of molecular basis of plant reaction to these natural environments or stresses has been an important focal point of research in the past decades (Garrett *et al*., 2011; Nishida *et al*., 2016; Wang *et al*., 2015). Many of these mechanisms have been utilized for engineering abiotic stretch tolerance in model and other crop plants by means of established biotechnological and/or breeding techniques. Achievement to cause stress tolerant plants has been accomplished to certain degree, which has brought about improved harvest yield. CRISPR-Cas9 technique can particularly enable the analysis of genome/gene functions and engineering abiotic stretch resistance in various crop plants (Barrangou and Marraffini, 2014; Chen *et al*., 2013). In spite of the fact that the essential use of this technique has been the generation of gene knock outs up until now, linking different applications will be imperative in the field of stress biology. The improvement of new regulatory module(s) from normally prevailing components (genes, promoters, epigenetic changes and small RNAs) can ease the engineering of regulatory/signaling and metabolic procedures to adjust plant abiotic stress resilience (Song and Zhang, 2017). Generally, the rapid pace of improvement and emerging utilizations of CRISPR technique promise its enormous contribution in understanding the gene regulatory systems basic abiotic response/modification and crop improvements systems to grow stress tolerant plants (Beneke *et al*., 2017; Jain, 2015; Lemak *et al*., 2013).

## DISCUSSION

Stress is commonly divided into two main types: biotic and abiotic. Biotic stress is observed when living organisms, for example, weeds, microorganisms, and creepy crawlies initiate harm to crop plant whereas abiotic stress is caused by a physical or any chemical compound in the rapid condition causing in changed development and yield (Huang *et al*., 2002; Jain, 2015). The plant development recovery is stimulated if there should arise an occurrence of the stress being for some time, of low intensity, or the plant being resistant. However it cannot endure this attack, its metabolic abilities are completely influenced, the phonological phases are exasperated and it eventually dead. The main abiotic stresses are drought, saltiness, and temperature extremes heat and cold (Kasuga *et* *al*., 1999; Kumar *et al*., 2009; Pandey *et al*., 2017b). Stress can be understood as a boost or impact which is outside the typical way of homeostatic control in a specified organism: if this stress resilience is surpassed, then mechanisms are triggered at molecular, biochemical, morphological, and physiological levels; but when it is controlled, another physiological state is set up, and homeostasis is restored. At that point when the stress is acquiescent, the plant may come back to the original form or to another physical condition (Krasensky and Jonak, 2012; Liu and Huang, 2000). The detecting of biotic or abiotic stress environments initiates signaling falls that trigger ion channels, kinase cascades, accumulation of hormones, for example, salicylic acid, ethylene, jasmonic, and abscisic acid and so on. These signals at last stimulate expression of particular divisions of resistance genes that principal to the association of general protection response (Otani *et al*., 1998; Pereira, 2016; Pérez-Clemente *et al*., 2013).

With a specific end goal to survive the stress conditions, plants effectively utilize pre-mRNA splicing as a tool to control expression of stress-responsive genes and reconstruct intracellular regulatory systems (Jiménez Bremont *et al*., 2013; Regnier and Kelley, 1981; Sanghera *et al*., 2011). These reactive oxygen species are additionally the resultants of changes in the metabolism of cell which are stimulated in reaction of different natural environment stresses terminating in oxidative stress. Reactive oxygen species stimulate as well as primary the essential and secondary signaling pathways in abiotic, pathogen stress, or oxidative by their detoxification or synthesis (Shi *et al*., 2015; Shriram *et al*., 2016; Taji *et al*., 2002). Temporary production of reactive oxygen species, likewise named as "respiratory burst," is a distinctive metabolism in biotic stress arising in primary plant-pathogen interaction or wounding. Different key players in reactive oxygen species signaling pathways incorporate zinc finger proteins and WRKY TFs. Reactive oxygen species are signals in ABA transduction pathway in guard cells in abiotic stretch. ABA stimulates hydrogen peroxide to lessen the water loss. Salicylic acid is additionally described to be a controller of reactive oxygen species in wounding (Pandey *et al*., 2017b; Umezawa *et al*., 2006; Wani *et al*., 2017).

## ACHIEVEMENTS AND FUTURE ASPECTS

The significance of optimum nourishment for human health and development is very much perceived. Unfavorable ecological factors, for example, drought, flooding, and heat etc., influence crop yields more than diseases and pests. Therefore, an important objective of plant researchers is to discover approaches to keep up high efficiency under stress and also growing crops with improved nourishing value. Genetically modified plants can prove to be potent supplements to those produced by traditional strategies for meeting the global demand for quality nourishments. Plants growing by genetic engineering cannot exclusively be used to improve yields and nutritious value but also in addition for increased resistance to different biotic and abiotic stresses. Incorporation of modern biotechnology, with regular traditional practices in a sustainable way, can fulfill the objective of achieving food security for present and as well as in future. Plant biotechnology can possibly report the different challenges in agriculture and society. Genetically modified techniques are being utilized to lessen the yield loss because of different stresses (biotic and abiotic) and are being utilized broadly for value increase in food crops by improvement with quality proteins, vitamins, zinc, carotenoids, anthocyanin, iron and many more. Insect resistant Bt crops and herbicide tolerant genetically modified crops which are now under commercial development have profited farmers through better weed and insect management, higher yields and lessened chemical pesticide utilize. The identification and optimum key stress genes and their resulting introgression for growing tolerant cultivars over traditional breeding are tedious. Plant biotechnology, in spite of being exorbitant in correspondence with traditional breeding, is exceptionally effective. Numerous stress responsive genes have been identified and effectively introduced into different plants to produce transgenic plants with improved resistance This involves the improvement of sets of indicators intended to improve the stress resistance. The benefits of biotechnology in the improvement of transgenic plants for proficient varieties are without a doubt; however their commercialization after appropriate field testing is as yet an inevitable reality.

## CONCLUSION

Plants are continually exposed with numerous biotic and abiotic stresses, which cause significant loss in crop yields around the world, while the importance for energy and food is on the ascent. Thus, it can be concluded that sustainable integration of traditional agricultural practices with modern biotechnology can empower the accomplishment of food security for present and as well as future. Genetically modified crops will be an important part of our life and the huge potential of biotechnology must be exploited to the advantage of mankind.

## REFERENCES

Aaliya, K., Z. Qamar, N.I. Ahmad, Q. Ali, F.A. Munim and T. Husnain (2016). Transformation, evaluation of gtgene and multivariate genetic analysis for morpho-physiological and yield attributing traits in *Zea mays*. *Genetika,* 48: 423-433.

Ahanger, M. A., N.A. Akram, M. Ashraf, M.N. Alyemeni, L. Wijaya and P. Ahmad (2017). Plant responses to environmental stresses—from gene to biotechnology. *AoB Plants,* 9: 00-00.

Altman, A. (2003). From plant tissue culture to biotechnology: scientific revolutions, abiotic stress tolerance, and forestry. *In Vitro Cellular & Developmental Biology-Plant*, 39: 75-84.

Ansai, S., T. Sakuma, T. Yamamoto, H. Ariga, N. Uemura, R. Takahashi and M. Kinoshita (2013). Efficient targeted mutagenesis in medaka using custom-designed transcription activator-like effector nucleases (TALENs). *Genetics*, 112: 147645.

Arora, L. and A. Narula (2017). Gene editing and crop improvement using CRISPR-Cas9 system. *Frontiers in Plant Science,* 8: 1932.

Barrangou, R. and L. A. Marraffini (2014). CRISPR-Cas systems: prokaryotes upgrade to adaptive immunity. *Molecular cell*, 54: 234-244.

Basu, S., V. Ramegowda, A. Kumar and A. Pereira (2016). Plant adaptation to drought stress. *F1000Research,* 5: 00-00.

Beneke, T., R. Madden, L. Makin, J. Valli, J. Sunter and E. Gluenz (2017). A CRISPR Cas9 high-throughput genome editing toolkit for kinetoplastids. *Royal Society Open Science*, 4: 170095.

Bhatnagar-Mathur, P., V. Vadez and K. K. Sharma (2008). Transgenic approaches for abiotic stress tolerance in plants: retrospect and prospects. *Plant Cell Reports,* 27: 411-424.

Blum, A. and A. Ebercon (1981). Cell Membrane Stability as a Measure of Drought and Heat Tolerance in Wheat 1. *Crop Science* 21: 43-47.

Bohnert, H. J. and R. G. Jensen (1996). Strategies for engineering water-stress tolerance in plants. *Trends in Biotechnology,* 14: 89-97.

Bressan, R., H. Bohnert and J.-K. Zhu (2009). Abiotic stress tolerance: from gene discovery in model organisms to crop improvement. *Molecular Plant,* 2: 1-2.

Bud, R. (2002). History of biotechnology. *Encyclopaedia of life sciences.*

Chan, Z. and H. Shi (2015). Improved abiotic stress tolerance of bermudagrass by exogenous small molecules. *Plant Signaling & Behavior*, 10: e991577.

Chen, B., L.A. Gilbert, B. A. Cimini, J. Schnitzbauer, W. Zhang, G.-W. Li, J. Park, E.H. Blackburn, J. S. Weissman and L. S. Qi (2013). Dynamic imaging of genomic loci in living human cells by an optimized CRISPR/Cas system. *Cell,* 155: 1479-1491.

Chen, K., and F. H. Arnold (1993). Tuning the activity of an enzyme for unusual environments: sequential random mutagenesis of subtilisin E for catalysis in dimethylformamide. *Proceedings of the National Academy of Sciences.* 90: 5618-5622.

DAI, H.-P., Z.-J. Yang and Y. Hu (2007). Research progress of cold resistance in Bermuda grass [J]. *Pratacultural Science,* 11: 022.

Downs, C. A., E. Mueller, S. Phillips, J.E. Fauth and C.M. Woodley (2000). A molecular biomarker system for assessing the health of coral (Montastraea faveolata) during heat stress. *Marine Biotechnology* 2: 533-544.

Eremina, M., W. Rozhon and B. Poppenberger (2016). Hormonal control of cold stress responses in plants. *Cellular and molecular life sciences*, 73: 797-810.

Evens, R. and K. Kaitin (2015). The evolution of biotechnology and its impact on health care. *Health Affairs,* 34: 210-219.

Ewing, J. F. (2001). Agricultural biotechnology: Is the international regulation of transgenic agricultural plants for the birds (and the bees). *Suffolk Transnat'l L. Rev.*, 25: 617.

Ezejiofor, T. I. N., U. E. Enebaku and C. Ogueke (2014). Waste to wealth-value recovery from agro-food processing wastes using biotechnology: a review. *British Biotechnology Journal,* 4: 418-481.

Fári, M. G., and U. P. Kralovánszky (2006). The founding father of biotechnology: Károly (Karl) Ereky. *International Journal of Horticultural Science*, 12: 9-12.

Garrett, R. A., G. Vestergaard and S. A. Shah (2011). Archaeal CRISPR-based immune systems: exchangeable functional modules. *Trends in microbiology*, 19: 549-556.

Geurts, A. M., G.J. Cost, Y. Freyvert, B. Zeitler, J.C. Miller, V. M. Choi, S. S. Jenkins, A. Wood, X. Cui and X. Meng (2009). Knockout rats via embryo microinjection of zinc-finger nucleases. *Science,* 325: 433-433.

Gianessi, L. P., C.S. Silvers, S. Sankula and J. E.Carpenter (2002). Plant biotechnology: current and potential impact for improving pest management in US agriculture: an analysis of 40 case studies. *National Center for Food and Agricultural Policy*, *Washington, DC*.

Guo, Y. H., Y. P. Yu, D. Wang, C.A. Wu, G. D. Yang, J. G. Huang and C. C. Zheng (2009). GhZFP1, a novel CCCH-type zinc finger protein from cotton, enhances salt stress tolerance and fungal disease resistance in transgenic tobacco by interacting with GZIRD21A and GZIPR5. *New Phytologist*, 183: 62-75.

Harlander, S. K. (2002). The evolution of modern agriculture and its future with biotechnology. *Journal of the American College of Nutrition*, 21: 161S-165S.

Hu, Z., J. Fan, K. Chen, E. Amombo, L. Chen and J. Fu (2016). Effects of ethylene on photosystem II and antioxidant enzyme activity in Bermuda grass under low temperature. *Photosynthesis Research*, 128: 59-72.

Huang, J., S. Rozelle, C. Pray and Q. Wang (2002). Plant biotechnology in China. *Science,* 295: 674-676.

Hussain, S. S., M.A. Kayani and M. Amjad (2011). Transcription factors as tools to engineer enhanced drought stress tolerance in plants. *Biotechnology Progress,* 27: 297-306.

Jain, M. (2015). Function genomics of abiotic stress tolerance in plants: a CRISPR approach. *Frontiers in Plant Science,* 6: 375.

Jiménez Bremont, J. F., M. Rodríguez Kessler, J.-H. Liu and S. S. Gill (2013). Plant stress and biotechnology. *BioMed Research International*, 2013.

Kasuga, M., Q. Liu, S. Miura, K. Yamaguchi-Shinozaki and K. Shinozaki (1999). Improving plant drought, salt, and freezing tolerance by gene transfer of a single stress-inducible transcription factor. *Nature biotechnology,* 17: 287.

Key, S., J. K. Ma and P. M. Drake (2008). Genetically modified plants and human health. *Journal of the Royal Society of Medicine*, 101: 290-298.

Kilian, J., D. Whitehead, J. Horak, D. Wanke, S. Weinl, O. Batistic, C. D'angelo, E. Bornberg-Bauer, J. Kudla and K. Harter (2007). The AtGenExpress global stress expression data set: protocols, evaluation and model data analysis of UVB light, drought and cold stress responses. *The Plant Journal,* 50: 347-363.

Krasensky, J. and C. Jonak (2012). Drought, salt, and temperature stress-induced metabolic rearrangements and regulatory networks. *Journal of Experimental Botany*, 63: 1593-1608.

Kumar, P., V. Gupta, A. Misra, D. Modi and B. Pandey (2009). Potential of molecular markers in plant biotechnology. *Plant Omics,* 2: 141.

Kumar, V., V. Shriram, P.K. Kishor, N. Jawali and M. Shitole (2010). Enhanced proline accumulation and salt stress tolerance of transgenic indica rice by over-expressing P5CSF129A gene. *Plant Biotechnology Reports,* 4: 37-48.

Lei, Y., X. Guo, Y. Liu, Y. Cao, Y. Deng, X. Chen, C.H. Cheng, I. B. Dawid, Y. Chen and H. Zhao (2012). Efficient targeted gene disruption in Xenopus embryos using engineered transcription activator-like effector nucleases (TALENs). *Proceedings of the National Academy of Sciences*, 2012: 15421.

Lemak, S., N. Beloglazova, B. Nocek, T. Skarina, R. Flick, G. Brown, A. Popovic, A. Joachimiak, A. Savchenko and A. F. Yakunin (2013). Toroidal structure and DNA cleavage by the CRISPR-associated [4Fe-4S] cluster containing Cas4 nuclease SSO0001 from Sulfolobus solfataricus. *Journal of the American Chemical Society,* 135: 17476-17487.

Liu, X. and B. Huang (2000). Heat stress injury in relation to membrane lipid peroxidation in creeping bentgrass. *Crop Science*, 40: 503-510.

Mahfouz, M. M., L. Li, M. Shamimuzzaman, A. Wibowo, X. Fang and J.-K. Zhu (2011). De novo-engineered transcription activator-like effector (TALE) hybrid nuclease with novel DNA binding specificity creates double-strand breaks. *Proceedings of the National Academy of Sciences*, 108: 2623-2628.

Mantell, S. H., J. Matthews and R. McKee (1985). *Principles of plant biotechnology: an introduction to genetic engineering in plants*. Blackwell Scientific Publications.

Marsh, D. (2003). Does New Zealand have an innovation system for biotechnology? *Technovation*, 23: 103-112.

Mohanta, T. K., T. Bashir, A. Hashem and E. F. Abd_Allah (2017). Systems biology approach in plant abiotic stresses. *Plant Physiology and Biochemistry*, 121: 58-73.

Mohanty, A., H. Kathuria, A. Ferjani, A. Sakamoto, P. Mohanty, N. Murata and A. Tyagi (2002). Transgenics of an elite indica rice variety Pusa Basmati 1 harbouring the codA gene are highly tolerant to salt stress. *Theoretical and Applied Genetics*, 106: 51-57.

Moore, F. E., D. Reyon, J.D. Sander, S. A. Martinez, J.S. Blackburn, C. Khayter, C.L. Ramirez, J. K. Joung and D. M. Langenau (2012). Improved somatic mutagenesis in zebrafish using transcription activator-like effector nucleases (TALENs). *PloS One*, 7: e37877.

Nakashima, K. and K. Yamaguchi-Shinozaki (2006). Regulons involved in osmotic stress-responsive and cold stress-responsive gene expression in plants. *Physiologia plantarum,* 126: 62-71.

Nishida, K., T. Arazoe, N. Yachie, S. Banno, M. Kakimoto, M. Tabata, M. Mochizuki, A. Miyabe, M. Araki and K. Y. Hara (2016). Targeted nucleotide editing using hybrid prokaryotic and vertebrate adaptive immune systems. *Science,* 353: aaf8729.

Nover, L., k. Bharti, P. Döring, S.K. Mishra, A. Ganguli and K.-D. Scharf (2001). Arabidopsis and the heat stress transcription factor world: how many heat stress transcription factors do we need? *Cell stress & chaperones,* 6: 177.

O'Mathúna, D. P. (2007). Bioethics and biotechnology. *Cytotechnology,* 53: 113-119.

Otani, M., T. Shimada, T. Kimura and A. Saito (1998). Transgenic plant production from embryogenic callus of sweet potato (Ipomoea batatas (L.) Lam.) using Agrobacterium tumefaciens. *Plant Biotechnology,* 15: 11-16.

Pandey, P., V. Irulappan, M. V. Bagavathiannan and M. Senthil-Kumar (2017a). Impact of combined abiotic and biotic stresses on plant growth and avenues for crop improvement by exploiting physio-morphological traits. *Frontiers in Plant Science,* 8: 537.

Pandey, S., D. Fartyal, A. Agarwal, T. Shukla, D. James, T. Kaul, Y.K. Negi, S. Arora and M. K. Reddy (2017b). Abiotic stress tolerance in plants: myriad roles of ascorbate peroxidase. *Frontiers in Plant Science,* 8: 581.

Pardo, J. M. (2010). Biotechnology of water and salinity stress tolerance. *Current Opinion in Biotechnology,* 21: 185-196.

Pauls, K. (1995). Plant biotechnology for crop improvement. *Biotechnology Advances,* 13: 673-693.

Pereira, A. (2016). Plant abiotic stress challenges from the changing environment. *Frontiers in Plant Science,* 7: 1123.

Pérez-Clemente, R. M., V. Vives, S.L. Zandalinas, M. F. López-Climent, V. Muñoz and A. Gómez-Cadenas (2013). Biotechnological approaches to study plant responses to stress. *BioMed Research International,* 2013.

Puspito, A. N., A.Q. Rao, M. N. Hafeez, M. S. Iqbal, K. S. Bajwa, Q. Ali, B. Rashid, M.A. Abbas, A. Latif and A. A. Shahid (2015). Transformation and Evaluation of Cry1Ac+ Cry2A and GTGene in Gossypium hirsutum L. *Frontiers in Plant Science,* 6: 943.

Qamar, Z., S. Riaz, I.A. Nasir, Q. Ali and T. Husnain (2015). Transformation and transgenic expression studies of glyphosate tolerant and cane borer resistance genes in sugarcane (*Sccharum officinarum* L.). *Molecular Plant Breeding,* 6.

Regnier, J. and K. Kelley (1981). Heat-and cold-stress suppresses in vivo and in vitro cellular immune responses of chickens. *American Journal of Veterinary Research,* 42: 294-299.

Rosse, R. B., B.L. Schwartz, R. E. Davis and S.I. Deutsch (1991). An NMDA intervention strategy in schizophrenia with" low-dose" milacemide. *Clinical Neuropharmacology,* 14(3): 268-272.

Sanghera, G. S., S. H. Wani, W. Hussain and N. Singh (2011). Engineering cold stress tolerance in crop plants. *Current Genomics,* 12: 30.

Sasson, A. (2005). *Medical biotechnology: Achievements, prospects and perceptions*. United Nations University Press.

Sawano, A. and A. Miyawaki (2000). Directed evolution of green fluorescent protein by a new versatile PCR strategy for site-directed and semi-random mutagenesis. *Nucleic Acids Research,* 28: e78-e78.

Shi, H., X. Wang, D.X. Tan, R. J. Reiter and Z. Chan (2015). Comparative physiological and proteomic analyses reveal the actions of melatonin in the reduction of oxidative stress in Bermuda grass (*Cynodon dactylon* (L). Pers.). *Journal of Pineal Research,* 59: 120-131.

Shi, H., T. Ye, B. Zhong, X. Liu and Z. Chan (2014). Comparative proteomic and metabolomic analyses reveal mechanisms of improved cold stress tolerance in bermudagrass (*Cynodon dactylon* (L.) Pers.) by exogenous calcium. *Journal of Integrative Plant Biology,* 56: 1064-1079.

Shinozaki, K. and K. Yamaguchi-Shinozaki (1996). Molecular responses to drought and cold stress. *Current Opinion in Biotechnology,* 7: 161-167.

Shinozaki, K. and K. Yamaguchi-Shinozaki (2007). Gene networks involved in drought stress response and tolerance. *Journal of Experimental Botany,* 58: 221-227.

Shriram, V., V. Kumar, R.M. Devarumath, T. S. Khare and S. H. Wani (2016). MicroRNAs as potential targets for abiotic stress tolerance in plants. *Frontiers in Plant Science*, 7: 817.

Slater, A., N. W. Scott and M. R. Fowler (2003). *Plant biotechnology: the genetic manipulation of plants*. Oxford University Press.

Song, Y. and D. Zhang (2017). The Role of Long Noncoding RNAs in Plant Stress Tolerance. *In: Plant Stress Tolerance.* pp. 41-68. Springer.

Stafford, A., P. Morris and M. Fowler (1986). Plant cell biotechnology: a perspective. *Enzyme and Microbial Technology,* 8: 578-587.

Sternberg, S. H. and J. A. Doudna (2015). Expanding the biologist's toolkit with CRISPR-Cas9. *Molecular cell,* 58: 568-574.

Taji, T., C. Ohsumi, S. Iuchi, M. Seki, M. Kasuga, M. Kobayashi, K. Yamaguchi-Shinozaki and K. Shinozaki (2002). Important roles of drought-and cold-inducible genes for galactinol synthase in stress tolerance in Arabidopsis thaliana. *The Plant Journal*, 29: 417-426.

Tu, J., K. Datta, M.F. Alam, Y. Fan, G.S. Khush and S.K. DATTA (1998). Expression and function of a hybrid Bt toxin gene in transgenic rice conferring resistance to insect pest. *Plant Biotechnology*, 15: 195-203.

Umezawa, T., M. Fujita, Y. Fujita, K. Yamaguchi-Shinozaki and K. Shinozaki (2006). Engineering drought tolerance in plants: discovering and tailoring genes to unlock the future. *Current opinion in biotechnology*, 17: 113-122.

Urnov, F. D., J.C. Miller, Y. -L. Lee, C.M. Beausejour, J. M. Rock, S. Augustus, A.C. Jamieson, M.H. Porteus, P. D. Gregory and C. Holmes (2005). Highly efficient endogenous human gene correction using designed zinc-finger nucleases. *Nature*, 435: 646.

Verma, A. S., S. Agrahari, S. Rastogi and A. Singh (2011). Biotechnology in the realm of history. *Journal of Pharmacy and Bioallied Sciences*, 3: 321-323.

Vinocur, B. and A. Altman (2005). Recent advances in engineering plant tolerance to abiotic stress: achievements and limitations. *Current opinion in Biotechnology*, 16: 123-132.

Wang, J.-W., A. Wang, K. Li, B. Wang, S. Jin, M. Reiser and R.F. Lockey (2015). CRISPR/Cas9 nuclease cleavage combined with Gibson assembly for seamless cloning. *BioTechniques*, 58: 161-170.

Wang, W., B. Vinocur, O. Shoseyov and A. Altman (2000). Biotechnology of plant osmotic stress tolerance physiological and molecular considerations. *In "IV International Symposium on In Vitro Culture and Horticultural Breeding 560*", pp. 285-292.

Wani, S. H., T. Dutta, N. R. R. Neelapu and C. Surekha (2017). Transgenic approaches to enhance salt and drought tolerance in plants. *Plant Gene*, 11: 219-231.

Wani, S. H., S.K. Sah, M. A. Hossain, V. Kumar and S.M. Balachandran (2016). Transgenic approaches for abiotic stress tolerance in crop plants. *In: Advances in Plant Breeding Strategies: Agronomic, Abiotic and Biotic Stress Traits*, pp. 345-396. Springer.

Wasternack, C. (2007). Jasmonates: an update on biosynthesis, signal transduction and action in plant stress response, growth and development. *Annals of botany*, 100: 681-697.

Weis, E. and J.A. Berry (1988). Plants and high temperature stress. *In: Symposia of the Society for Experimental Biology*, Vol. 42, pp. 329-346.

Yoshida, T., Y. Fujita, H. Sayama, S. Kidokoro, K. Maruyama, J. Mizoi, K. Shinozaki and K. Yamaguchi-Shinozaki (2010). AREB1, AREB2, and ABF3 are master transcription factors that cooperatively regulate ABRE-dependent ABA signaling involved in drought stress tolerance and require ABA for full activation. *The Plant Journal*, 61: 672-685.

Zalatan, J. G., M.E. Lee, R. Almeida, L.A. Gilbert, E.H. Whitehead, M. La Russa, J.C. Tsai, J. S. Weissman, J. E. Dueber and L. S. Qi (2015). Engineering complex synthetic transcriptional programs with CRISPR RNA scaffolds. *Cell*, 160: 339-350.

Zhou, Y., X. Zhang and R. H. Ebright (1991). Random mutagenesis of gene-sized DNA molecules by use of PCR with Taq DNA polymerase. *Nucleic Acids Research*, 19: 6052.

Zhu, J.-K. (2002). Salt and drought stress signal transduction in plants. *Annual review of Plant Biology*, 53: 247-273.

(*Accepted for publication December 2018*)