








Maize breeding for abiotic stress tolerance: An alternative to face climate changes

Tiago Corazza da Rosa¹, Ivan Ricardo Carvalho^{2,*}, Danieli Jacoboski Hutra², Leonardo Cesar Pradebon², Marlon Vinícius da Rosa Sarturi², José Antonio Gonzalez da Silva² and Vinícius Jardel Szarecki¹

¹Universidade Federal de Pelotas (UFPEL), Rio Grande do Sul, Brasil. ²Universidade Regional do Noroeste do Estado do Rio Grande do Sul (UNIJUÍ), Ijuí, Brasil. *Corresponding author, E-mail: carvalho.irc@gmail.com

ABSTRACT

Maize breeding faces several challenges when the matter is abiotic stresses. For many years, the focus was to develop genotypes adapted to optimal environmental conditions, however, the need to ensure yields under unsuitable and unstable conditions of a climate-changing world is undeniable. Therefore, this review is addressed to the main abiotic stresses that jeopardize maize production worldwide, presenting an overview regarding losses and impacts imposed by them, stating what has been achieved through conventional and molecular plant breeding techniques, and the future prospects on this subject. The conventional breeding added to molecular techniques bring great expectations for developing abiotic stresses tolerant maize genotypes. Universities and research companies worldwide have contributed to expand and spread basic and essential knowledge, however, the entrance of large multinational companies might revolutionize the field. Genetic modified hybrids and projects of continental coverage will introduce many innovations and alternatives to ensure food security for the increasingly growing world population.

Keywords: Physiological stress, selection of genotypes, traits of importance, cultural practices, sustainable agriculture, stress tolerance mechanisms.

INTRODUCTION

Over many years, maize (*Zea mays* L.) genetic breeding had its focus on developing genotypes for ideal environments, prioritizing the development of high yielding cultivars, however highly resource demanding. Such resources as land, water for irrigation, fertilizers, pesticides, labor and time are becoming increasingly scarce in a world with 9.1 billion people expected for 2050, 30% more than today (Food and Agriculture Organization of the United Nations [FAO], 2013). Besides being a staple food globally used for human and animal nutrition, maize is largely employed for biofuels production (United state Department of Agriculture [USDA], 2010). Therefore, maize production must duplicate in order to meet this large energetic and food demand expected for the incoming decades (Rosegrant et al., 2008).

This situation imposes a difficult task for maize breeders, as higher yielding genotypes must be developed, while the growing conditions become less stable and less suitable. New agricultural lands are still available; however, they are limited and often present abiotic restrictions as drought, salinity, acidity, specific elements toxicity or deficiency, and waterlogging (Witcombe, Hollington, Howarth, Reader, & Steele, 2008). Also, misuse, poor cultural practices and adverse climate conditions increase the degradation of already used arable lands by salinization and acidification, being estimated that more than 50% of the world's arable land will be salinized by 2050. World climate change is expected to affect agriculture in still slightly known ways, increasing temperatures, drought or flooding in some areas, carbon dioxide concentration, resulting in great instability for agricultural activity, jeopardizing global food security in medium term (Gornall et al., 2010). In view of this, maize genetic breeding aimed at abiotic stress tolerance has a key role in developing more efficient genotypes, contributing for a sustainable agriculture.

Despite its noble mission, plant breeding for abiotic stresses present several complicating factors, such as incomplete understanding about stress tolerance mechanisms; lack of knowledge about genetic elements that contribute to stress tolerance; less interest compared to breeding for favorable conditions; technical limitations of molecular-assisted breeding; frequent yield reductions through the introduction of genes that improve stress tolerance (Gilliham, Chapman, Martin, Jose, & Bastow, 2017). Also, the effects of genotype x environment interaction under abiotic stresses are more expressive, (Bänziger & Cooper, 2001), while the

heritability of characters tends to decrease (Bänziger, Betrán, & Lafitte, 1997) and reduce genetic gains, making breeding progress more difficult.

Grain yield in maize and most other crops presents low heritability and great influence of environment, which is potentialized under abiotic stress conditions. The tolerances for salinity and drought, for instance, are also complex traits, controlled by polygenes, possibly negatively correlated between themselves and with grain yield (Di, Tian, Zu, Meng, Zeng, & Wang, 2015). Therefore, an efficient way to increase the efficiency of maize selection for abiotic stresses tolerance is through direct or indirect selection in stressful environments. However, indirect selection through a secondary trait of high heritability, and highly correlated with the objective character may be more efficient than direct selection (Ziyomo & Bernardo, 2013). Molecular approaches as quantitative trait loci (QTLs) mapping and posterior marker-assisted selection (MAS) (Gupta, Balyan, & Gahlaut, 2017; Tsonev et al., 2009), and most recently the genome wide selection (GWS) (Shikha et al., 2017) are expected to bring great contributions for breeding abiotic stress tolerant maize genotypes.

Therefore, this review is addressed to the main abiotic stresses that jeopardize maize production worldwide, presenting an overview regarding losses and impacts imposed by them, stating what has been achieved through conventional and molecular plant breeding techniques, and the future prospects on this subject.

ABIOTIC STRESSES

Next, a discussion of the main abiotic stresses will be presented.

Drought

Water deficit is an environment stress that affects majority of the agricultural areas in all continents around the world. Drought is considered the most damaging stress in maize production, as this species appears to be more responsive to water deficiency than other cereals (Daryanto, Wang, & Jacinthe, 2016). Drought may decrease maize yield from 39% to 100%, as it affects every stage of plant growth and development, since germination until physiological maturity (Aslam et al., 2013).

Maize begins to be affected by drought during germination. Water absorption, imbibition and metabolic activity are hindered under limited water availability, which decreases germination. After germination, water deficit reduces plumule and radicle elongation, resulting in a poor seedling development (Gharoobi, Ghorbani, & Nezhad, 2012). These effects will compromise a uniform emergence and field establishment. Drought stress significantly reduces cell division and elongation, decreasing root growth, leaf formation, and consequently, the photosynthetically active area (Aslam, Maqbool, & Cengiz, 2015). Root expansion is disturbed under drought conditions, reducing length, volume, density and ramification of the radicular system, which compromises the ability of exploring the soil for water and nutrients uptake (Nejad, Bakhshande, Nasab, & Payande, 2010).

Under drought conditions, abscisic acid (ABA) accumulation is increased in the leaves and triggers the stomatal closure as an attempt to reduce water losses (Wilkinson & Davies, 2010). It slows down the photosynthesis and decreases photoassimilates production (Farooq, Wahid, Kobayashi, Fujita, & Basra, 2009). In case of drought prevalence, photosynthetic activity is abruptly declined by leaf area reduction, decrease in turgor pressure and stomatal closure. This process limits photosynthetic CO₂ fixation and activates the molecular O₂ for extensive production of reactive oxygen species (ROS). These reactive oxygen species (ROS), such as superoxide radical (O₂⁻), hydrogen peroxide (H₂O₂) and singlet oxygen (1O₂), damage the chloroplast and destroy cell membranes (Taiz & Zeiger, 2012), leading to chlorosis development.

Drought also has severe effects on maize reproductive stage due to the low translocation of photoassimilates for reproductive tissues, negatively affecting pollen and silk development, pollination, embryo, endosperm and kernel development (Taiz & Zeiger, 2012). Pollen is affected by drought mainly because of dehydration (Aylor, 2004), decreasing its viability and affecting pollination. Drought delays silk exposure and elongation, resulting in incompatibility with pollen release. The embryo formation may be aborted under drought stress due to the accumulation of reactive oxygen species (ROS) and abscisic acid (ABA) in the ovaries, which triggers embryo abortion (Setter & Flannigan, 2001). Kernel filling is affected by the lack of photoassimilates being translocated to the grains, resulting in reduced grain size, mass and consequently yield per area.

Some physiological and morphological adaptations are known to confer tolerance to drought in maize. Among them, it is speculated that the up-regulation of ABA mediated antioxidant synthesized in roots and

translocated to leaves enhance the adaptation of maize to drought stress (Souza et al., 2014). Also, osmotic adjustment is a process of solute accumulation in dividing cells which helps maintaining cell turgor under water deficit (Basu, Ramegowda, Kumar, & Pereira 2016). Moreover, genotypes that prioritize root deepening and broadening are more productive since they improve water absorption and maintain higher values of stomatal and mesophyll conductance than genotypes that prioritize shoot growth under drought conditions.

Several maize breeding programs aimed at drought tolerance have been carried out. Most of the pioneering work performed by the International Maize and Wheat Improvement Center (CIMMYT) in the 1980s, exploited the natural variability of maize populations, and were conducted in the same environment where the populations were selected, limiting the selection gains and range of utilization of the improved populations developed. A partnership between CIMMYT and the International Institute of Tropical Agriculture (IITA) implemented the project “Drought Tolerant Maize for Africa (DTMA)”, releasing 200 drought tolerant and N-efficient maize varieties to 13 countries located in the sub-Saharan Africa (SSA), achieving yield increases and positive socio-economic effects in a short-term survey (Wossen et al, 2017).

Nowadays, multinational companies claim to have achieved substantial progresses developing maize hybrids more tolerant to drought. Pioneer company released the Optimum® AQUAmax™ maize hybrids, which are supposed to 5.0% of average yield advantage over commercial hybrids under drought conditions (DuPont Pioneer, Johnston, IA, USA). Syngenta release the Artesian™ technology (Syngenta Seeds, Minnetonka, MN, USA), both promoted by traditional breeding. The third drought tolerant technology is Monsanto’s Genuity™ Drought Gard™ (Monsanto Co., St. Louis, MO, USA), promoted as conferring drought tolerance through the introduction of a transgenic trait. These progresses were possible due to the employment of high-throughput genotyping, which provides a great number of molecular markers to assist in marker-assisted selection and genome wide prediction (Habier, Fernando, Kizilkaya, & Garrick, 2011). Such techniques enable to evaluate an extensive number of lineages in early generations, keeping in the program only those with high frequency of the genes of interest, optimizing time and resources. Unfortunately, such technologies are still not well spread due to its cost and complexity, and their practical utilization is almost restricted to large companies. However, plenty of researches are being conducted around the world on genomics and big data analysis, and advances are expected to arrive soon and aid developing drought tolerant maize genotypes.

Extreme temperatures

Recent advances of the agricultural frontiers through new areas of south America, Asia and Africa, added to the effects of global climate changes, may expose maize to a range of temperatures beyond the ideal for this species. Events of extreme temperatures are characterized by periods of short-time duration with temperatures over 5°C above or under the expected for a specific region (Hatfield & Prueger, 2015). However, these episodes of extreme temperatures are becoming more intense, more frequent and last longer (Meehl et al., 2007), affecting maize yield in several ways.

The concrete effects of heat on maize yield in numbers is not clear, mainly because stresses caused by high temperatures are commonly associated to drought, being difficult to evaluate it separately. Researchers estimate that each Celsius degree of temperature increase results in 5 to 50 % of maize yield reduction (Lobell & Field, 2007; Schlenker & Roberts, 2009; Hatfield et al., 2011). However, in order to fully comprehend the effects of heat on maize yield, it is necessary to verify the duration and severity of the extreme temperature wave according to the phenological stage of maize plants, because some of these stages are more sensitives to temperature variations.

High temperature stress affects several stages of maize growth and development. It is reported that temperatures over 41 °C inhibit embryo growth, while the hydrolysis of endosperm and cotyledon reserves continues, which reduces seedlings vigor and germination rate. In addition, temperatures above 38 °C reduce maize photosynthetic activity (Naidu, Moose, Al-shoaibi, Raines, & Long, 2003). Heat stress also affects the viability of maize pollen, as temperatures above 35 °C together with low vapor pressure drastically decrease pollen viability (Dupuis & Dumas, 1990). However, the most pronounced effects occur during the reproductive phase (Cheikh & Jones, 1994), especially during the phase of endosperm cell division and amyloplast biogenesis in maize kernels. High temperatures decrease the rate and duration of endosperm cell division and thus, the number of cells formed. In addition, a substantial decrease in starch granule number is also observed. Hence, the perturbation of the primary events in endosperm development results in a disruption of subsequent dry matter accumulation in developing maize kernels

(Jones, Roessler, & Ouattar, 1985). It is believed to occur due to a hormonal unbalance triggered by heat, with the decrease of cytokinin hormone, which regulates cell division in the endosperm, followed by the increase of abscisic acid (ABA) concentration in the kernels (Cheikh & Jones, 1994).

On the other hand, low temperature is one of the most important abiotic factors limiting growth, development and distribution of plants. It affects mainly temperate regions, where maize crop is often exposed to low temperatures during its early development stages, resulting in poor photosynthetic performance (Leipner, Fracheboud, & Stamp, 1999). Low temperature affects germination, seedling growth, early leaf development and overall maize crop growth and productivity (Nguyen, Leipner, Stamp, & Guerra-Peraza, 2009). Severe cold impairs chloroplast function, thereby inhibiting photosynthesis, leading to cell death and premature senescence (Gómez, Vanacker, Buchner, Noctor, & Foyer, 2004). Frost represents a hazard to maize mainly in spring, when plants are small, and in autumn when physiological maturity is approaching. Temperatures of -1°C to -2°C for periods of less than twelve hours may be devastating for young plants and maize grains at filling stage (Eagles, 1979). Low temperatures freeze the liquid content within cells. As result, the liquid volume expands and breaks cell wall, irreversibly damaging them (Krause, Grafflage, Rumich-Bayer, & Somersalo, 1988).

Tolerance to extreme temperatures is a quantitatively inherited trait highly responsive to genotype x environment interaction, making it difficult to achieve resistant genotypes (Chen, Xu, Velten, Xin, & Stout, 2012). The natural variability of maize populations has been extensively screened in the search for favorable genotypes to be used in breeding programs aimed at extreme temperatures tolerance (Nguyen, Leipner, Stamp, & Guerra-Peraza, 2009). The findings of more tolerant genotypes to specific locations are not rare in the literature (Khodarahmpour, Choukan, Bihamta, & Majidi-Hervan, 2011; Magorokosho Vivek, MacRobert, & Tarekegne, 2010; Cairns et al., 2013).

However, there is still a lack of widely and applicable results. On 2013, a CIMMYT led alliance consisting of Purdue University, Pioneer Hi-Bred, seed companies, and South Asian public sector launched the project Heat Stress Tolerant Maize for Asia (HSTMA), with the goal of developing heat tolerant maize genotypes for southern Asia, a region that has been increasingly experiencing extreme heat conditions (FAO, 2005). Among what has been accomplished by this project so far, it was presented that heat and drought tolerance are not the same and that the lipid composition in cellular membranes (particularly the chloroplasts) are critical to the stability of maize under heat stress. They have applied Genome-wide association Selection (GWAS), QTL mapping, and linkage analysis to identify candidate genes for heat tolerance, generating six 6 multi-parent synthetic populations promising for crossings and double haploid production. Hybrids were generated and tested in several Asian countries, evidencing positive and promising results, however more field trials are required to consistently prove their efficiency (FAO, 2005).

Regarding the tolerance to low temperatures, the most adapted populations are reported to be from cold areas of Europe. Moreover, genotypes belonging to the European Flint germplasm showed better cold tolerance than those originating from the American continent (Revilla et al., 2014). It is reported that cold tolerance is controlled by QTLs associated with other traits such as chlorophyll content or photosynthesis, where 19 of them explained between 5.7 and 52 % of the phenotypic variance (Strigens et al., 2013). However, great results to avoid cold stress were achieved through selection of reduced growth cycle genotypes, avoiding critical periods of early and late growing stages (Revilla et al., 2016).

Soil salinization and sodification

Soil salinization and sodification is one of the major abiotic stresses that limits maize yield worldwide. It is estimated that more than 800 million hectares of cultivated land is salt/sodium affected, which is over 6% of the world's arable area (Rengasamy, 2010), and represents about 20% of the irrigated land (FAO, 2005). Salinization is the accumulation of water soluble-salts (K^+ , Mg^{2+} , Ca^{2+} , Cl^- , SO_4^{2-} , CO_3^{2-} , HCO_3^-) (Rengasamy, 2006), whereas sodification is the accumulation of Na^+ to levels that impacts on agricultural production, and it is individually addressed due to its impact on agriculture (Shani & Ben-Gal, 2005).

The main effects of salinization and/or sodification on maize plants is a high osmotic stress due to low external water potential, ion toxicity by sodium and/or chloride, or imbalanced nutrition due to the interference with the uptake and transport of essential nutrients (Farooq et al., 2009). The high concentrations of salts in the soils as sodium and chloride interferes with the availability of other essential elements such as calcium and potassium (Munns, James, & Läuchli, 2006). Toxic levels of sodium and salts in plant tissues damage membranes and subcellular organelles, resulting in abnormal development and plant mortality (Quintero, Fournier, & Benlloch, 2007). Therefore, it impacts all growing and developing

stages of maize, impairing germination and seedling growth by creating an unsuitable environment, affecting leaf and root expansion, drastically reducing photosynthesis, grain filling and grain yield (Netondo, Onyango & Beck, 2004).

Some mechanisms are suggested to increase maize tolerance to salinity. Firstly, there is the osmotic tolerance, which is regulated by long distance signalization and reduces shoot growth before the accumulation of Na^+ . The second mechanism is ion exclusion, where Na^+ and Cl^- transport is limited by the root system, reducing the accumulation of toxic concentrations of Na^+ and Cl^- within stem and leaves. The last of them is tissue tolerance, with the sequestration of salt molecules and their storage in the vacuoles (Roy, Negrão, & Tester, 2014).

There is reported the presence of natural variability in maize populations capable of conferring some levels of tolerance to salinity (Mindari, Maroeto, & Syekhiani, 2011). Usually, the screenings for tolerant genotypes are based on germination and seedling development traits (Murillo-Amador, López-Aguilar, Kaya, Larrinaga-Mayoral, & Flores-Hernández, 2002), however, field trials and entire plant cycle evaluations are also performed. Several works reported in the literature present the occurrence of salinity-tolerant maize genotypes (Akram et al., 2010; Hoque, Jun, & Guoying, 2015). However, as example of the extreme temperature tolerance case, little practicable and applicable progress has been made, as stated by Bänziger and Araus (2007), “there is the lack of application in applied maize breeding programs of traits and selection strategies much more than the lack of understanding of the underlying complex mechanisms has prevented breeding progress for salinity tolerance in maize”.

Soil Acidity, aluminum, iron and manganese toxicity

Soil acidity is considered a major abiotic effect that impacts crops production worldwide. It is estimated that around 3.95 billion hectares, which represents 30% of the world's ice-free land and 50% of the world's arable land, are affected by acidity (Uexküll & Mutert, 1995). Soil acidity is measured by pH scale, which evaluates the activity of hydrogen (H^+) ions in the soil solution. The increase in soil acidity result in less availability for essential plant nutrients, as nitrogen (N), phosphorous (P), calcium (Ca), and magnesium (Mg), and more availability of toxic elements, as Aluminum (Al), Manganese (Mn), and iron (Fe) (Velásquez, Souza-Jr., Narro, Pandey, & León, 2008). It is reported that adverse effects on maize yield occur under pH of 5,6, (Sánchez & Salinas, 1981). However, major toxicity damages on maize are caused by Al toxicity because it inhibits root growth, reduces water and nutrient uptake and interferes in several physiological processes of crop development (Roy, Sharma, Talukder, & Talukder, 1988). Also, the excess of Mn strongly inhibit chloroplast structure and function (Doncheva et al., 2009). The Fe toxic levels initiate processes that damage lipids, proteins and DNA (Connolly & Guerinot, 2002).

Maize presents two major mechanisms to avoid the effects of Al, Fe and Mn toxicity. One is characterized by the release of organic acid anions such as malate, citrate and oxalate, which bound to Al^{3+} , Mn^{2+} , and Fe^{3+} in the rhizosphere, forming stable, nontoxic complexes (Ma, Ryan, & Delhaize, 2001). This process will limit toxic ions uptake by the roots and minimize its harmful effects in maize plants. The other mechanism is an internal response, characterized by the production of specific proteins capable of forming complexes with toxic aluminum (Basu, Basu, & Taylor, 1994).

Due to the soil acidity often be linked to any element toxicity, tolerance mechanisms are individually approached, focusing on genotypes or genes that confer better performance under unsuitable conditions. The natural variability of maize populations has been constantly screened worldwide seeking for tolerance to specific acidity and element toxicity conditions, revealing some positive results regarding adaptability and grain yield (Richard, Munyinda, Kinkese, & Osiru, 2015; Coelho et al., 2015). Deeper studies into maize genome revealed that Al tolerance is a quantitative trait, with five quantitative trait loci (QTLs) controlling the largest part of the phenotypic variation (Maron et al, 2010). On the other hand, other studies relate that the gene MATE1 is the major responsible for Al tolerance in maize (Maron et al., 2013). Detailed and conclusive studies addressing iron (Fe^{2+}) and manganese (Mn^{2+}) stress tolerance in maize are still scarce in the literature, therefore, the best option for now is to choose tolerant genotypes adapted to specific locations, added to an adequate soil management and liming. This option may be more expansive, however, it enables maize to be grown in a wide range of soils.

Waterlogging

Waterlogging or flooding is a serious issue in low rainfed lands. It affects a large fraction of the world's agricultural land, being estimated that 6% of the earth surface is temporarily flooded or susceptible to its occurrence (Ferreira, Coelho, Magalhães, Gama, & Borém, 2007). Besides, unpredictable rain patterns due to worldwide climate change are expected to increase the occurrence of waterlogging, (Cairns et al., 2012), which results in severe reductions of maize yields. Waterlogging corresponds to the saturation of the soil with water, totally or partially reducing the content of O₂ in the soil, preventing plants respiration and leading to cell death (Ahmed et al., 2013).

As a non-wetland crop species, maize is considered susceptible to anaerobic soil conditions mainly during germination and early growth stages (Zaidi, Rafique, Rai, Singh, & Srinivasan, 2004). However, the extent of damage due to waterlogging stress varies significantly throughout the plant developmental stages (Zaidi et al., 2015). Under low oxygen availability, maize plants reduce ATP synthesis from oxidative phosphorylation (Drew, 1997). Thereby, respiration pathways shift from oxidative to fermentative (Kato-Noguchi & Morokuma, 2007), however, anaerobic ATP production is not sufficient to attend the plant's full demand (Bailey-Serres, Lee, & Brinton, 2012). It leads to the lack of chemical energy for the most diverse cellular activities, and after certain period, it results in plant death.

Tolerance may be achieved by maize genotypes through three primary factors, which are the ability to grow adventitious roots at the soil surface during flooding conditions, the capacity to form root aerenchyma, and tolerance to toxins such as Fe²⁺ and H₂S under reducing soil conditions (Zaidi et al., 2015). Secondary physiological adaptations also contribute for increasing maize tolerance to waterlogging. Among them, the most effective, are the ability to transport oxygen internally to submerged tissues (Maricle & Lee, 2002), ability to keep stomata open and maintain photosynthesis rates during flooding (Parent, Crèvecoeur, Capelli, & Dat, 2011), and the capacity to avoid oxidative damage from excess light energy not used in CO₂ fixation.

Researches have evidenced the presence of QTLs responsible for aerenchyma, adventitious roots formation, and tolerance to reducing soil conditions in teosinte (*Zea mays*) (Mano, Muraki, & Takamizo, 2006; Mano & Omori, 2007). These genes of interest were successfully introgressed into maize genome through artificial crosses (Mano & Omori, 2013). Inbred lines were generated from the genotypes containing the introgressed genes, which later were crossed to generate F1 hybrids. These hybrids presented increased waterlogging tolerance compared to the original populations (Mano & Omori, 2015). Several advances are supposed to arise shortly through pyramiding of genes of interest into inbred lines, as the release of flooding tolerant F1 maize hybrids are expected for Japan within a few years (Mano, Omori, Tamaki, Mitsuhashi, & Takahashi, 2016).

FINAL COMMENTS

Currently, there are many efforts being conducted worldwide to develop new maize varieties or hybrids with tolerance to abiotic stresses. Recent advances in molecular biology and vegetal biotechnology bring great expectations and possibilities for engineering crops at their genetic levels, in order to overcome the most diverse stresses possible to occur in growing fields. The founding of a wide range of molecular markers and their employment on marker-assisted breeding revolutionized the effectiveness and accuracy of plant breeding. Also, transgenic approaches are very promising tools for modern plant breeding programs.

The discovery of specific genes or gene families which confer improved productivity and adaptation to abiotic stresses, added to the possibility of transferring them to maize or any other major crop, is an extremely powerful alternative for plant breeding. Transgenic plants can also be used as sources of new cultivars or as new sources of variation for breeding programs (Jewell, Campbell, & Godwin, 2010). Monsanto has already released transgenic maize hybrids supposedly tolerant to drought stress, under the commercial label of Genuity® DroughtGard®. At first, these hybrids were launched in USA, and are expected to arrive soon in China and South America (Truitt, 2013). Several other studies addressing enhanced salinity tolerance in transgenic maize plants through specific foreign genes are reported (Wei, He, Li, Li, & Zhang, Di et al., 2015).

The manipulation of pathways by up or down regulating the expression of specific genes become another matter target of several studies nowadays. It has been experimentally employed for developing maize tolerant to heat and drought stresses (Huo, Wang, Wei, & Xia, 2016; Casaretto et al., 2016). These

advanced technologies keep great expectations, however, some of them are tentatively, some of them are reality, and some of them are hopeful for a short future or for a long run. In fact, knowledge is being constantly increased side by side to techniques enhancement and valuable information gathering, which will bring many solutions for current problems (Ulukan, 2011). The conventional breeding will keep its ground, as the ideal scenario is to find the easiness of molecular techniques and their cost effectiveness to be integrated to conventional breeding methods, allying the field expertise of breeders to advanced molecular tools and approaches, and then, ensure the effectiveness and viability of breeding abiotic stresses tolerant maize.

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