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Review on Mechanisms of Drought Tolerance in Sorghum (Sorghum bicolor (L.) Moench) Basis and Breeding Methods

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Sorghum is grownup in semi-dry to arid regions of the world and helps as the primary food for about half a billion public in sub-Saharan Africa and Asia. Drought is one of the most restrictive abiotic factors causal meaningfully to yield loss in arid and semi-arid surroundings and continues to be a challenge for plant breeders, regardless of many decades of research. This problem can alleviate by developing crops that are well adapted to moisture constraint areas. Sorghum (Sorghum bicolor (L.) Moench) is an important drought tolerant crop in such areas and is a good crop model for evaluating mechanisms of moisture stress tolerance. Direct selection for yield under drought has been the major breeding policy and was successful in some crops but not for all. Drought varies the structure and function of plants. sympathetic of the influence, mechanisms and traits underlying drought tolerance is vital to grow drought-tolerant cultivars. Proof of identity and evaluation of important physiological traits would aid and fortify molecular breeding and genetic engineering stand in targeting and delivering traits that improve drought tolerance capability of crops. There is an overlay amongst different osmotic stresses and the selection of appropriate drought valuation methods. The benefits of genetic engineering have been realized in crop improvement for quality traits, and several promising genes have emerged in the past decade as candidates for drought tolerance. Combining the physiological traits that would sustain yield under drought, and integrating elite quantitative trait loci (QTL) and genes underlying these traits into high-yielding cultivars, would be a successful approach.

Key words: Drought tolerance, physiology, breeding, genetics, mechanisms, *Sorghum bicolor*, stay green, resistance.

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INTRODUCTION

Sorghum [*Sorghum bicolor* (L.) Moench, [2n = 2x = 20] is the emerging model crop species for the tropical grasses with C4 photosynthesis. Sorghum is the fifth most important Cereal crop and occupies the second position among the staple food grains in semi-arid tropics. It remains a critical component of food security for more than 300 million in Africa (Kidanemaryam *et al.*, 2018) and it is a staple crop for more than 500 million people in 30 sub-Saharan African and Asian countries (Mindaye *et al.*, 2016)while it is primarily grown as feed grain in the developed world.

Sorghum is predominantly grown by smallholder farmers in Ethiopia. The highest proportion (74%) of the grain produced is consumed at the household level, with the remainder being used for sale and seed purposes at local level. The grain is used for preparation of different local staple food products such as leavened bread (*injera*), porridge and local beverages that require specific grain quality characters additionally the Stover, which has uses for animal feed, fuel and construction of fences and shelters, is often valued as highly as grain yield, hence taller varieties are highly favored by farmers (Mindaye *et al.*, 2016).

Sorghum grows across a wide geographic area at various altitude, day length, rainfall, and temperature regimes. Consequently, it is well adapted to withstand harsh conditions, which are the characteristic feature of tropical regions. The crop requires relatively less water than other important cereals such as maize and wheat. However, yield potential of the crop is significantly limited due to drought and heat stresses within the tropics and subtropics necessitating sorghum breeding for drought tolerance and productivity (Kidanemaryam *et al.*, 2018). In Ethiopia, which is the sixth largest sorghum producing country in the world, sorghum contributes 17% of the total annual cereal grain production. It is grown in highly diverse environments, which can be broadly classified into three major agro ecology; highland areas >1900 m, intermediate areas between 1600 and 1900 m and lowlands areas <1600 m above sea level, which are characterized by distinct edaphic and climatic conditions mainly drought (Mindaye *et al.*, 2016).

Amelework *et al.*,(2015) reviewed that drought is one of the most important factors that affect crop production worldwide. Climate changes will increase the frequency of drought and flood occurrence, particularly in many countries in Africa. There is indication that climate change may lead to a change in the frequency and severity of drought events. For instance, by 2050, water shortages are expected to affect 67% of the world's population. Improving drought tolerance of food crops is an important objective in many crop-breeding programs. However, selection for drought tolerance is difficult because of inconsistency in testing environments and interaction between stages of plant growth and environment. The genetic mechanisms for the expression of drought tolerance in crop plants are poorly understood. Since drought tolerance is a complex trait controlled by many genes, and is dependent on the timing and severity of moisture stress, it is one of the most-difficult traits to study and characterize (Kebede H. *et al.*, 2001).

Drought resistance in sorghum is a composite trait influenced by several genes coding for various traits contributing towards drought tolerance. For many decades' plant breeders have concentrated on some traits that were incorporated to plant survival under drought such as lower leaf canopy and reduced transpiration. But such like traits are not essentially correlated with high yield and led the breeders to evolve cultivars with poor yield under stress condition (Ali *et al.*, 2009).Among the C4 cereals, Sorghum bicolor is the species most suited to environments that are prone to drought. Its tolerance to drought is a consequence of morphological and anatomical characteristics (thick leaf wax, deep root system) and physiological responses (osmotic adjustment, stay green, quiescence) (Fracasso *et al.*, 2016). The high genetic variability among sorghum genotypes and the relatively small size of its genome make this cereal a good model for the identification of drought related genomic regions and genes valuable to unravel the high complexity of drought tolerance related traits.

The impact of moisture stress on crop yield is dependent on the stage of plant development. In sorghum Anthesis and grain filling stages appear to be the most vulnerable growth stages. occurrence of water deficiency at these stages may result in reduced yield and/or complete crop failure (Kidanemaryam *et al.*, 2018).The growing instability of seasonal rainfall patterns and temperature conditions has prompted greater attention towards the genetic improvement of traits that maximize grain yield in water-limited environments (Mace *et al.*, 2012).

Direct selection of traits that has positive correlation for improving yield potential under drought-stressed circumstances through conventional breeding has been troubled. Because of their polygenic resistor, epistasis, significant genotype by environment (G × E) interaction and quantitative trait loci to environment (QTL× E) interaction (Bankole *et al.*, 2017).

Crop production is constrained by several biotic, abiotic and socio-economic factors. Amongst the most important abiotic constraints, drought is the most important. Therefore, understanding of the physiological mechanisms and genetic control of drought in crops is important as a base for improving the production and productivity of crops in the arid and semi-arid tropics. In general, this review tried to recapitulate, the physiological mechanisms, genetic control and breeding methods of drought tolerance in sorghum followed by the following specific objectives:

1. To review the mechanisms of drought tolerance in sorghum.
2. To assess the nature of sorghum in relation to drought.
3. To recommend best crop breeding strategy in drought alleviating research in sorghum.

DROUGHT EFFECT AND TOLERANCE MECHANISMS OF SORGHUM

Effects of drought on plant development and productivity of Crops

One of the most important abiotic stress factors that limit crop production worldwide is water availability. In a comparison of cereal crops grown under drought and little or no drought conditions in developed countries, drought reduces wheat yield by 61% and barley yield by 53%. Sorghum is known for its drought tolerance among cereal crops. It has a dense and deep root system, an ability to reduce transpiration through leaf rolling and stomatal closure, and its capability to reduce metabolic processes to near dormancy under extreme drought. Because of these, sorghum can survive dry periods and resume growth once soil moisture becomes available. Despite its tolerance to drought, sorghum still suffers yield losses of 60–90% to drought, depending on severity (Kole, 2015).

Rauf *et al.*, (2015) reviewed that, drought is occurring on all continents with varying intensity and frequency. The horn of Africa is strongly affected by drought almost every 12 years but drought intensified during the years 2009-2011. During the same period, wheat yield was reduced by 45% in Kenya. Similar trends were also observed in Australia when drought reduced wheat yield by 46% in 2006. Around 17% of the global cultivated area was affected by drought during the period 1980-2006. Drought principally affects crops cultivated under rainfed conditions, which represent 80% of the total cultivated area worldwide. According Rauf *et al.*, (2015), at least 23 million ha of rainfed rice (20% of the total rice area) in Asia are cultivated under drought-prone conditions. In Pakistan, around 33% of wheat, 27% of maize, 56% of sorghum and millet, 52% of barley, 77% of chickpea, 84% of pulses, 24% of rapeseed and mustard and 100% of castor bean are cultivated under rainfed conditions and are consequently drastically affected by drought. The part of the cultivated area permanently affected by drought at the world level is estimated to be around 28% in sorghum, 20% in wheat, 19% in barley and 19% in maize.

In various plants, physiological traits that are linked with drought tolerance when a plant is endangered to drought stress include greater cell growth, photosynthesis and biomass accumulation during pre-flowering stress, high pollen viability, seed set and seed numbers at flowering and improved stay green, photosynthesis and seed size during post flowering drought (Kidanemaryam *et al.*, 2018). Other traits are (i) leaf rolling and wax content which will help in reducing leaf temperature, (ii) yield traits such as seed filling duration and seed filling rate which will increase seed size, and (iii) root traits such as increased root growth and water absorption which increases water uptake (Mutava, 2009).

Sorghum response to drought

Sorghum plants have a wide range of physiological responses to regulate their water status for environmental adaptation, thus to ensure their reproduction and survival. During drought stress, growth reduction, water movement modification linked to the metabolism adjustment, the stomata closure and the reduction of photosynthesis are observed on susceptible cultivars. Drought is unpredictable and may occur at any stage of growth (Ouedraogo, 2015).

A multiplicity of morphological and physiological modifications has been identified in response to drought stress in plants. Many traits whose existence or manifestation is associated with plant adaptability to drought-prone environments have been identified(Ribaut *et al.*, 1999). They involve root morphology and rooting depth, plant architecture, variation in leaf cuticle thickness, stomatal regulation, osmotic adjustment, antioxidant capacity, hormonal regulation, desiccation tolerance (membrane and protein stability), and maintenance of photosynthesis through persistent green leaf area (stay-green)(Shehzad *et al.*, 2014). Plants expressing a variety of genes associated with these morphological and physiological traits tolerant to abiotic stresses have been identified. However, direct selection of these traits for improving yield potential under drought-stressed circumstances through conventional breeding has been troubled by their polygenic resistor, epistasis, significant genotype by environment (G × E) interaction and quantitative trait loci to environment (QTL× E) interaction (Ouedraogo, 2015).

The intricate interactions of plant function with its internal water status are at the root of the complex relationship between the plant and its environment. Partly because of this interaction plant response to drought stress varies with the rate of stress development, the duration of stress, and plant age when stress develops (Ribaut *et al.*, 1999).

Physiological mechanisms of drought tolerance

Amelework *et al.*, (2015)reviewed that drought resistance as mechanisms of drought avoidance, recovery, survival and tolerance. These drought tolerance mechanisms are associated with plant survival and production. Drought avoidance is defined as the ability of plants to conserve water at the whole plant level through decreasing water loss from the shoots or by more efficiently extracting water from the soil. However, drought tolerance is defined as the ability of plants to withstand water deficit while maintaining appropriate physiological activities to stabilize and protect cellular and metabolic integrity at tissue and cellular level. Survival is the ability of the crop to survive drought, irrespective of the yield it produces, while production is the ability of the crop to grow and yield under water stress conditions. Drought tolerance is a complex trait which affected by many genes and environmental conditions. The responses of different plants, species, or genotypes to drought are variable in relation to developmental stage, duration of the occurrence of drought and evolutionary adaptation of the crop (Bibi *et al.*, 2012).

Drought resistance, involves the interaction of different morphological structures, physiological functions, and biochemical expressions (Amelework *et al.*, 2015).Effects of water deficit at the whole-plant level are manifested by effects on plant phenology, growth and development, source–sink relations and plant reproduction processes. An understanding of the various physiological traits controlling/ regulating crop responses to drought is required for identifying natural genetic variation for drought tolerance. These traits can be broadly classified as shoot- and root-related traits (Manavalan *et al.*, 2017).

The other best and effective mechanism is Drought escape that plants avoid drought by completing life cycles before the onset of a dry period to sustain some reproduction(Manavalan *et al.*, 2017).Early maturing genotypes were drought escaping, and had lower evapotranspiration due to smaller leaf area. In nature, drought escapers are characterized by rapid Phenological development after the incidence of rain and extension of the reproductive phase of development while good soil moisture conditions prevail (Abraha, 1999). In using drought escape as a solution, some of the potential yield is sacrificed in return for improved stability under stress.

Leaf rolling and stomatal conductance

In most plants, stomatal conductance and leaf rolling have been found to be reliable physiological signs of drought tolerance. Both are strongly associated with leaf water potential. On the other hand, these two mechanisms are influenced by different factors because stomatal conductance is controlled by soil moisture dependent root signals, while leaf rolling is controlled by leaf water potential. The strong correlation of leaf rolling and leaf water potential allows breeders to use leaf rolling as a visual scoring benchmark for selecting for drought resistance in plants. The rolling of leaves usually occurs following the reduction in leaf water potential. However, the degree of leaf rolling depends on the ability of the plant to adjust osmotically at low leaf water potential (Amelework *et al.*, 2015).However, the degree of leaf rolling rest on the ability of the plant to amend osmotically at low leaf water potential. Plants with high osmotic adjustment develop less leaf rolling, and hence, reduced leaf rolling is considered as an pointer of a greater degree of desiccation avoidance, through a deep root system (Morka, 2015).

Drought tolerant genotypes exhibit lower stomatal conductance associated with increased leaf temperature, which gives rise to high transpiration efficiency and lower carbon isotope discrimination. enlarged leaf temperature and transpiration percentage are due to a controlled transpiration cooling system brought by stomatal closure. Osmotic adjustment had a significant role in maintaining stomatal conductance and accumulation of solutes that extend time for CO2 assimilation and increase the net assimilation rate under drought condition(Morka, 2015). decrease in stomatal conductance, reduction of intercellular carbon dioxide, decreased chlorophyll content, ultra-structural changes in chloroplast, alteration in electron transport, decreased activity of Rubisco and sucrose accumulation. At the plant level, drought stresses will result in reduction in growth and affect photosynthesis by reducing leaf area, enhancing stomatal closure, decreasing water status in the leaf tissues, and reducing the rate of CO_2 assimilation. Ultrastructural changes in chloroplast will also affect photosynthesis electron transport and CO2 assimilation and hence impairment of adenosine triphosphate (ATP) synthesis and Ribulose-1,5- bisphosphate (RuBP) generation (Mutava, 2009).

The significance of using these traits as physiological indicators of plant drought adaptive mechanisms depends on the crop species and the environment. Under conditions where there are no sophisticated instruments to measure transpiration efficiency and stomatal conductance, leaf rolling is good indicator of drought tolerance(Assefa, 2012).

Root system architecture

The Plants avoid dehydration by increasing water uptake in the soil profile and adapt to the chemical and physical soil constraints, particularly under drought conditions, thanks to the morphological plasticity of their root system (Rauf *et al.*, 2015). Root length (56.6%) was the highest towards drought tolerance, indicating root length was least effected by water stress among all the seedling traits. Root length is an important trait against drought stress in plant varieties; in general, variety with longer root growth has resistant ability for drought and to absorb nutrient and moisture available in the soil (Bibi *et al.*, 2012).

Drouth tolerance was found to be highly associated with root characteristics such as root thickness, root length density, number of thick roots, root volume, and root dry weight. It was also found that number of thick roots, root thickness, and root length density were highly associated with leaf water potential and field visual drought scoring using drying leaf. Drought stress adapted plants are often characterized by deep and vigorous root systems. Higher root length, shoot length with lower leaf water potential, osmotic potential and turgor pressure under water stress could be utilized as selection criteria for drought tolerance in sorghum at seedling stage. The most drought tolerant and susceptible genotypes might be used further in hybridization programmes to create maximum genetic variability(Bibi *et al.*, 2012).

Fresh and dry root weight was also decreased due to water stress in sorghum. Dry and fresh weights of roots were decreased during the drought period as their leaf size remained small tominimize transpiration, ultimately plant dry weight also reduced. Specifically, dry root weight (DRW) has been utilized as a selection criterion for drought tolerance by many plant breeders. Water uptake by the root is a complex parameter that depends on root structure, root anatomy, and the pattern by which different parts of the root contribute to overall water transport (Bibi *et al.*, 2012). In moisture stress conditions, plants with sufficient P supply exhibited higher hydraulic conductivity than P deficient plants. Therefore, plants with sufficient P are found to be more droughts tolerant, and also have a higher ability to recover after drought.

Osmotic adjustment, dehydration tolerance and transpiration efficiency

Tuberosa, (2012) reviewed that, OA is a metabolic process entailing a net increase in intercellular solutes in response to water stress. As soil moisture declines, OA favors turgor maintenance, and hence the integrity of metabolic functions. Importantly, OA can bias estimates of the value of relative water content, as has been shown in wheat and barley. OA has been implicated in sustaining yield under conditions of water deficit in oilseed Brassica species, chickpea, cotton, rice, sorghum, maize, teff, barley and wheat.

Similarly, Osmotic adjustment improves crop productivity through delaying leaf rolling and leaf tissue death. As leaf rolling and leaf senescence decreases, the effective leaf area for photosynthesis increases. In a study on sorghum genotypes, those with high osmotic adjustment exhibited a 24% higher yield than genotypes with low adjustment, when exposed to a post Anthesis drought stress. The yield difference observed was both in grain size and grain number, and it was associated with higher harvest index is reviewed by (Amelework *et al.*, 2015).

Amelework *et al.*, (2015) look over that, dehydration tolerance as the capacity of the plant to maintain higher turgor potential in the plant cell under moisture stress conditions. Dehydration tolerance is usually measured by tissue's water level, which is expressed in terms of water potential. This characteristic is highly associated with cell membrane stability to maintain high level of cell water potential under drought condition. Plants' that are dehydration tolerance physiological and biochemical activities of the cell, which are essential for growth and yield of the plant are not strictly constrained by water stress.

Transpiration efficiency (TE) is defined as total biomass produced per unit of water transpired. Improvement of TE means maximizing crop production per unit of water used (Thevar, 2008).Genetic variation in TE has also been found in sorghum using gas-exchange properties, traditional lysimetric assays and field evaluation. Among sorghum genotypes significant variation in TE and water treatments has been observed. Sorghum genotypes with low internal CO_2 concentration and enhanced photosynthetic capacity may be associated with high TE. High TE was strongly correlated with increased biomass accumulation, rather than with reduced water use.

Solute accumulation and storage sugar solutes

Solutes are low-molecular-weight and highly soluble compounds that are usually nontoxic even at high cytosolic concentrations. Generally, they protect plants from stress through different means such as contribution towards osmotic adjustment, detoxification of reactive oxygen species, stabilization of membranes, and native structures of enzymes and proteins. Under drought stress, transgenic plants had a higher percentage of seed germination, better-developed root systems, more biomass, increased solute accumulation, less cell membrane damage, less growth retardation, shorter ASI, and much higher grain yields than WT plants(Jewell *et al.*, 2010).

stay-green / non-senescence/

Leaf senescence is a programmed cell death resulting from drought and other environmental stress factors. It is characterized by loss of chlorophyll and progressive decline in photosynthetic capacity. Post-flowering drought tolerance is expressed by the ability of a plant to maintain photo synthetically active leaf area after physiological maturity, a character known as stay green or non-senescence (Amelework *et al.*, 2015).

Subsequently, Mindaye (2006) reviewed that, breeding for stay green trait is becoming a fundamental strategy for increasing crop production in water-limited conditions. Genotypes possessing the stay green trait maintain more photo synthetically active leaves than genotypes not possessing the trait. The longevity and photosynthetic efficiency of the leaves of stay green plant was shown to be associated with the nitrogen status of the leaves. Plants with the stay green trait contain high content of cytokinin's and basal stem sugars than do senescent genotypes. Moreover, it has also an advantage to resist stalk rot disease. The stalks of stay green genotypes have the capacity to transport water continuously under drought conditions. In addition to this, the relative water content in the apical leaves of sorghum lines containing stay green trait was about 81% whereas it was only 38% in the non-stay green lines. The stay green trait might add value to the stalks that may enhance the quality of stalk as feed sources. Results of some previous studies indicated that content and concentration of non-structural carbohydrate in the stay green plant relatively after grain harvest has been higher than the non-stay green types.

Chlorophyll fluorescence and reflection indices

Drought affects the photosynthetic activity of leaves as a consequence of altered chlorophyll a fluorescence kinetics. The analysis of changes in chlorophyll fluorescence kinetics provides de- tailed information on the structure and function of the photosynthetic apparatus, especially photosystem II. Manavalan and Nguyen, (2017) reviewed that, Measurement of chlorophyll fluorescence was used as a non-destructive measure of drought avoidance in wheat, barley, rice and maize. Use of spectral reflection indices and imaging for crop monitoring would allow us to detect stress at an early stage.

Canopy temperature

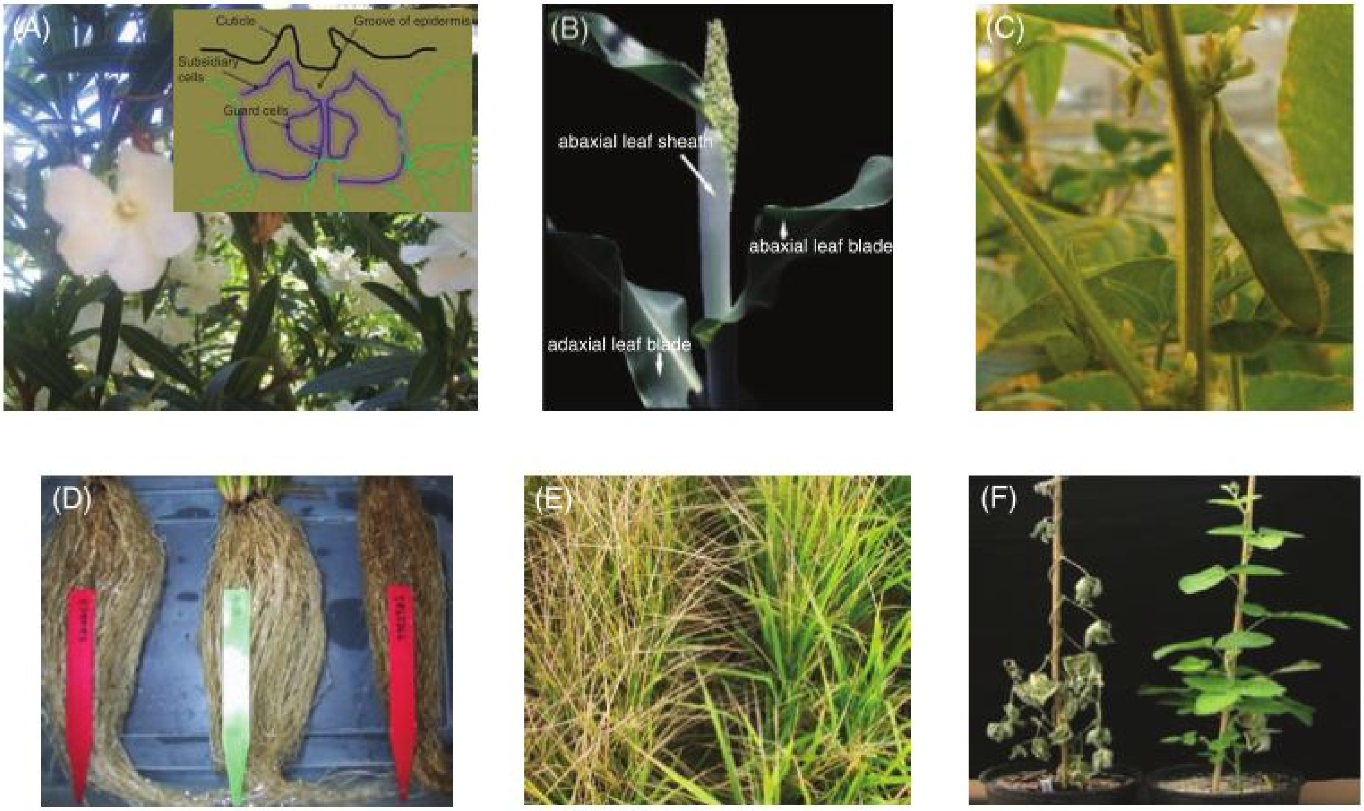
Canopy temperature is considered as a sister/ surrogate trait in relation to stomatal conductance, as they are directly related. Plants with high stomatal conductance transpire more and thus maintain a cooler canopy temperature. Canopy temperature and its depression relative to ambient air temperature indicate how much transpiration cools the leaves under the hot and humid climate that is typically associated with drought stress. Canopy temperature, measured with an infrared thermometer, has been used as a secondary trait to evaluate cultivars for drought tolerance in rice, wheat, sorghum and maize. New remote-sensing tools based on the use of thermal imaging to estimate plant water status at field level are gaining in importance. Use of thermography has been proposed for high-throughput phenotyping of tropical maize adaptation in water stress (Manavalan *et al.*, 2017).

Anatomical modifications to reduce water loss (sunken stomata/glaucousness/ epicuticular wax/leaf pubescence)

Plants such as *Nerium oleander*, *Ficus spp*., and modified leaves of certain plants (pine needles), avoid drought by sunken stomata, which is an anatomical adaptation. In these species, stomata are sunken below the epidermal plane (Figure 1.A). The guard cells are located in a depression, creating a more humid microclimate in the boundary layer. Air in the depression is slightly protected from wind, and any molecule of water that escapes from the stoma may remain in the depression long enough to actually bounce back into the leaf rather than evaporate (Figure. 1.A). Glaucousness is the waxy covering of the plant cuticle that renders a dull-white or bluish- green cast referred to as bloom in crops such as sorghum and wheat (Figure 1.B). Genotypes with low cuticular transpiration rates can conserve relative water content (RWC)in water-deficient conditions. Glossy leaf trait was found to be associated with seedling stage drought tolerance in sorghum. A positive association between water use efficiency and glaucousness was reported in wheat, peas and maize. Leaf pubescence density is considered as an adaptive trait for drought tolerance in soybean (Figure 1.C). Pubescent hairs reflect excess radiation and reduce epidermal conductance. A significant negative correlation between epidermal conductance and water use efficiency in soybean supports the importance of these traits (Manavalan *et al.*, 2017).

Genetics of drought tolerance

Drought resistance is a complex trait, expression of which depends on action and interaction of different morphological (earliness, reduced leaf area, leaf rolling, wax content, efficient rooting system, awn, stability in yield and reduced tillering), physiological (reduced transpiration, high water-use efficiency, stomatal closure and osmotic adjustment) and biochemical (accumulation of proline, polyamine, tetrahalide, etc., increased nitrate reductase activity and increased storage of carbohydrate) characters. Very little is known about the genetic mechanisms that condition these characters (Mitra, 2001).



*** Source: (Manavalan *et al.*, 2017).

Figure 1. Anatomical, morphological and genetic modifications in plants exhibiting drought tolerance

Existence of genetic variation for resistance to drought has been demonstrated in numerous crop species. Drought resistance is estimated as yield stability in crops like wheat, rice maize, barley and sorghum; leaf water potential in sorghum, soybean, cotton wheat and rice; Leaf rolling in rice; root growth in sorghum, rice, oat, wheat and maize; osmotic adjustment in wheat and sorghum; stomatal conductance in crops like upland cotton and so on. The genetic control of these traits ranged from oligogenic to polygenic in nature.

A number of traits related to drought resistance have been identified and mapped; however, the stay-green trait is recognized as the most crucial drought resistance trait in sorghum. In plants life system, there is a direct or indirect Relationship between drought resistance traits and yield. The trait that is expected to associated positively with drought resistance need to be investigated carefully to establish the relationship. To do this, the use of suitable techniques for its measurement is developed, then germplasm is screened to assess the genetic variability for the trait. Correlations between such traits and yield may indication for drought resistance/tolerance. The findings of the research must be confirmed by comparing with near isogenic lines for each individual trait.

Breeding methods for drought tolerance

Understanding the mechanisms of drought tolerance and breeding for drought-resistant crop plants has been the major goal of plant biologists and crop breeders. However, drought tolerance is recalcitrant to molecular genetics study mainly due to our limited awareness of specific traits linked to drought tolerance. Furthermore, it is difficult to conduct drought stress treatments in a quantitative and reproducible way. These difficulties have significantly impeded research on plant drought tolerance. Consequently, the biological basis for drought tolerance is still largely unknown and few drought tolerance determinants have been identified. The slow pace in revealing drought tolerance mechanisms has hampered both traditional breeding efforts and use of modern genetics approaches in the improvement of drought tolerance of crop plants (Xiong *et al.*, 2006).

Generating and selecting for new combinations of genes to produce genotypes with superior trait performances than those of existing genotypes, within the target environment, is the major objective of plant breeding. In any breeding programmes, defining the critical traits to improve grain yield in a given target environment is critical. Identification of important traits depends on the degree of influence of a trait on yield, expression of the trait at a whole plant level, the nature of the target environment. The greater flexibility of sorghum in adapting to diverse climatic conditions have resulted in the evolution of tropical and temperate sorghum varieties. The tropical varieties are characterized by being tall, late maturating with low harvest indices, photoperiod sensitivity and poor population performance. They are generally adapted to low population levels and exhibit little response to improved agricultural practices (fertilization and mechanized harvesting). The temperate sorghum varieties, on the other hand, are characterized by dwarf stems, early maturity, high yields, and less dry matter per plant (Tadesse, 2006).There are many Breeding methods for drought resistance in crop enhancement programs. Among them Plant introduction, Selection (mass or pure line selection), Hybridization, Mutation and Gene transfer are commonly used and the most intensively used in many research areas (Kidanemaryam *et al.*, 2018).

In breeding for drought tolerance, a pure line selection method has been used in many national and regional sorghum research programmes in Africa and Asia. Conversely, pedigree and bulk selection methods are commonly used in most international and national breeding institutions. Pedigree selection in segregating populations derived from planned crosses is the dominant breeding strategy to develop pure line varieties and hybrid parents in sorghum. If the transfer of only a few traits relating to drought resistance to a high yielding cultivar is required, then backcrossing is the appropriate breeding method (Amelework *et al.*, 2015).

Molecular Breeding for Drought Tolerance

Molecular breeding approaches through identification of QTL and marker-assisted selection offer an opportunity for significant improvements in the drought tolerance of crops. To gain momentum in the progress of breeding for drought tolerance, two sets of cutting-edge tools are being actively utilized. One involves the use of molecular markers to better understand the genetic basis of drought tolerance and to select more efficiently for this trait. For traits that are difficult to phenotype at a large scale, such as root traits and OA, molecular tagging with specific markers will facilitate the efficient identification of genes controlling these traits. The other tool, known as participatory plant breeding, offers a more active role to farmers, who make important contributions to selection for better drought tolerance as they closely observe plant performance. Identification of genetic hot- spots in chromosomes through genome map- ping across crop species will aid in prioritizing the set of genes to be used for crop improvement under drought. The combination of the above two approaches was employed successfully for breeding drought-tolerant rice and sorghum (Manavalan *et al.*, 2017).

Marker-assisted back crossing (MAB) has been used to introgressed these QTLs into inbred hybrid parental lines for the subsequent production of improved hybrids (Shehzad *et al.*, 2014).

Biotechnological Methods to Improving Drought Tolerance

There are different biotechnological approaches for drought improvement. Mainly Genomics, Proteomics, Metabolomics, Genetic engineering and others. The techniques for gene transformation of crop plants have been applied for identification of genes responsible for drought resistance and their transfer. Mainly two approaches, namely targeted and shotgun approach facilitate genetic engineering to obtain transgenic plants conferring drought resistance (Mitra, 2001).

Innovative strategies for gene discovery based on germplasm screening and functional genomic research is required for developing drought resistant crops. Genomics research results will supply information on the biology of traits, especially for complex quantitative traits such as drought. Plant functional genomics has emerged as a new and rapidly evolving scientific discipline to study the functions of genes. Gene expression profiling through microarrays has been used successfully to identify genes regulating drought resistance in crops. Most of the drought responsive genes identified from transcriptomics are classified into ABA-dependent, ABA-independent and DREB2A/ubiquitination related mechanisms. Genes associated with the production of osmolytes, amino acids (proline) and amines (glycine betaine and polyamines) are differentially expressed in response to drought stress (Manavalan *et al.*, 2017).

Proteomics, the systematic analysis of (differentially) expressed proteins, is a tool for the identification of proteins involved in cellular processes. Proteomics provides information on the amount of the gene products, their isoforms and which post-transcriptional modifications regulate protein activation. Several drought-responsive proteins have been identified by proteomics in different plant tissues (Manavalan *et al.*, 2017).

Plant metabolism is highly altered in response to drought, and downstream transcript-level changes lead to the alteration in quality and quantity of various metabolites. Metabolic profiling can give an instantaneous snapshot of the physiology and biochemical changes in the cell. In addition to gene transcripts, proteins and metabolites, small RNAs (miRNAs, siRNAs) are reported to be involved in adaptive responses to abiotic stresses (Manavalan *et al.*, 2017).

Genetic engineering has been successfully applied to identify and transfer different genes responsible for biosynthesis of different metabolites such as proline, tetrahalide and polyamines from different organisms to crop plants through a targeted approach. Exploration of wide genetic variation of relevant characters, consideration of more genes at a time to transfer through breeding or genetic engineering method, application of antisense RNA technique, assessment of polypeptides induced under drought and multidisciplinary approach should be included in the future research programmes for drought resistance (Mitra, 2001).

The applications of genetic engineering of food crops have already led to examples of improved drought tolerance and increased yield under drought (Manavalan *et al.*, 2017). Genetic engineering technology can assist the production of agronomically desirable sorghum plants that exhibit increased resistance to pests, pathogens, abiotic stress and enhanced nutritional qualities. But, few laboratories in the world are addressing sorghum crop improvement through novel methods. So far, limited numbers of genes conferring agronomic advantages have been introduced through Agrobacterium and particle bombardment. The most effective method to-date is Agrobacterium based sorghum transformation which has high transformation efficiency and is known to produce plants with single copy inserts with complete gene integration (Girijashankar *et al.*, 2009).

Drought Evaluation Methods

In order to realize the balance between the different drought tolerance traits and their values to plants, it is critical that drought evaluation studies include measurement of both plant growth condition (soil water status) and plant responses including tissue water status and its regulators such as leaf area and stomatal conductance. With the transgenic and mutant approaches to characterize gene function under stress, the most important requirement is reliable and repeatable drought evaluation methods. Specific physiological and biochemical conditions had to be met to test these plants in growth chambers, greenhouses or in field conditions.

Technologies such as automated plant phenotyping platforms to study the plant responses to soil water deficit under controlled conditions, automated rotating lysimeter systems, non-destructive measurement of plant water status over time using portable nuclear magnetic resonance equipment and other precision equipment to quantify plant water use should be exploited. Rain-out shelter facilities provide a useful measure to evaluate germplasm in field conditions with precise control over irrigation. The emerging field of phonemics focuses on the characterization of the whole-plant phenotype. The Plant Accelerator (formerly the Australian Plant Phonemics Facility) is a world-leading plant growth and analysis facility based at the Waite Campus of the University of Adelaide. This facility utilizes digital imaging technologies, high capacity computing and robotics, which allow the dissection of traits that contribute to drought and salinity tolerance for large populations of plants. Plant phenotyping has become an increasingly important tool to quantify the link between the genotype and the environment, and exciting new discoveries are concrete the way to experimentally explore the entire genotype environment matrix for individual factors and their interactions (Manavalan *et al.*, 2017).

Role of Marker assisted selection

In utmost breeding programmes, the genetic enhancement for drought resistance is accomplished through selection for yield because of low heritability of yield under stress and the spatial as well as temporal variation in the field environment, conventional breeding approaches are slow. Whereas molecular markers such as restriction fragment length polymorphism (RFLP), random amplified polymorphic (RAPD) and isozyme will facilitate to develop drought-resistant genotypes more effectively as their expressions are independent of environmental effects (Mitra, 2001).

MAS is highly valuable in QTL analysis which enables the identification of genes responsible for superior performance across a wide range of environments (Ribaut *et al.*, 1999).After identification of the molecular markers associated with yield or other morphological traits related to drought resistance, those markers could be used as a selection criterion for drought resistance. The application of marker-assisted selection in evolving drought- resistant genotypes is in an experimental stage; more specifically just identification of RFLP markers associated with osmotic adjustment, stay green, root traits71–74 has been achieved.

CONCLUSION

Moisture stress is one of the greatest factors in reducing yield in the arid and semi-arid tropics. For the reason that, the period of drought stress under variable environments is unpredictable, generally the effects of stress on grain yield is difficult. Understanding the genetic and physiological basis of drought resistance in plants is crucial when breeding is for drought resistance reduced plant size in terms of small and narrow leaf structures and genetic dwarfing of the plant has a great importance for drought resistance. Genetic dwarfing, on the other hand, increases the efficiency of plants in balancing the translocation of assimilates translocation between the developing grain and the vegetative organs.

Sorghum is well-thought-out as a drought tolerant crop that has good adaptation to versatile antagonistic environments. Stress on sorghum can occur at any stage of its growth. Stresses during mid-season and terminal stages of crop growth have more severe effects on grain yield. The reduction in yield under initial mid-season stress is small that the plant can recover when rainfall restarts; However, if the stress extends to the prolonged mid-season and the post flowering terminal stages, yield drop is more severe because the prospect to recover is gradually lost. There are three general strategies for plant to survive in drought situations: escape, avoidance, or tolerant. Besides, non-senescence (stay green) in sorghum genotypes is the trait that can alleviate drought stress effect on sorghum and it is positively correlated with yield and yield components. The challenges posed by drought are not unbeatable; they can be overcome with sufficient understanding of the genetic basis of tolerance and the resources available to the research community. Use of advanced breeding methods, molecular and biotechnological techniques will enhance stress tolerances of sorghum with an appropriate evaluation method for drought tolerant genotypes.

RECOMMENDATION

As sorghum is grown below marginal and cruel environments, the options to shift to other worthwhile crops are limited. Investments ought to go with the flow towards breeding varieties incorporating the best attributes desired via end users (farmers). Breeding efforts for value added traits like tolerance to drought, grain mold, charcoal rot, shoot fly, stem borer and Striga have to preserve as yield loss due to these elements is to the track of 30–50%.

Breeding for sorghum improvement is obligatory so that it will alleviate poverty. due to the fact sorghum can develop in harsh environments and it is simple to enhance genetically those tendencies which can be answerable for that particular pressure. specifically, drought tolerance is the primary trait want to improve which will growth sorghum productiveness. further to this breeding for excellent need to must get interest specially tendencies favored through farmers. so as to accomplish boom in sorghum manufacturing cutting-edge breeding tools like molecular procedures, biotechnological strategies are the maximum broadly used globally starting from identification of favorable trait to moving from species to species even from organism to organism.

the second one precedence is to reproduce varieties to boom the shelf life of grain and reduce the undesirable attributes inside the grain like reducing fat and tannin content and phenol compounds, followed via improving/retaining high-quality of the flour and exploring the fitness advantages and nutraceutical fee. business demand for grain-primarily based alcohol is also anticipated to propel a double-digit boom charge. Parallelly, commercialization of Sorghum ought to need to get attention for the pleasant boom and valuable impact on countrywide and international economic boom.

Researches must search for to answer the subsequent question: What are the prospects for genetic development in drought-tolerant plants? objectives must to challenge on yield an update of the techniques, in research and improvement, with the intention to offer farmers with plants showing a better drought tolerance ability evaluate to the current varieties for better yield and overall performance.

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