Debesa et al., Adv Crop Sci Tech 2023, 11:11

Advances in Crop Science and Technology

Expert Review Open Access

Review on Breeding Strategies for Drought Tolerance in Maize (*Zea mays L.*)

Bulo Debesa[1]*, Dereje Ayalneh[1], Estefanos Habtemariam[1], Tefera Mitiku[1], Talef Wendwesson[1], Sefiya Nur[1], Tesfahun Getachew[1], Berhane Sibhatu[1], Admasu Mitiku[2] and Lemi Yadessa[2]

[1]*Ethiopian Institute of Agricultural Research, Melkassa Agricultural Research Centre, P.O. Box 436, Adama Ethiopia*
[2]*Jimma University College of Agriculture and Veterinary Medicine, P.O. Box 378, Jimma, Ethiopia*

Abstract

Drought is the single most common cause of severe food shortage in developing countries and climate change is predicted to further exacerbate its impact. It is also estimated that some 1.8 billion people will suffer from water shortage and two thirds of humanity will be affected by water stress by 2025 compromising cereal production sub-Saharan Africa and Latin America. In maize, moisture stress is most devastating when it occurs at flowering with causing yield losses of 45-60%. Therefore, the development of drought-tolerant lines becomes increasingly more important. Multidisciplinary approach, which ties together breeding, physiology and molecular genetics, can bring a synergistic understanding to the response of maize to water deficit and improve the breeding efficiency. Managed stress screening approaches provide an opportunity to keep heritability high and adequately representing abiotic stress factors that are relevant in the target environment. It is desirable that more breeding programs use high-priority abiotic stresses in their mainstream breeding program, so that more experience on breeding approaches that effectively target stress environments can be gained. The objective of this paper will focus on the major strategies or approaches used by breeding programs for improving drought tolerance maize.

Keywords: Managed stress; Heritability

Introduction

Maize *(Zea mays L.)* along with wheat and rice provides at least 30% of the food calories to more than 4.5 billion people in 94 developing countries where one-third of children are malnourished (Hoisington et al., 1996 and Von Braun et al., 2010). By 2050, the demand for maize in the developing world will be almost double to the current demand (Chaudhary et al., 2014). However, an estimated 15% to 20% of maize grain yield is lost each year due to drought and such losses may further increase as droughts become more frequent and severe because of climate change (FAOSTAT (2010) [1].

In SSA, maize covers more than 25 million hectares that produce 38 million metric tons of grain (Shiferaw et al., 2011). The average maize yield in SSA is 1.8 t per hectare (Smale et al., 2011), which is very low compared to that of other maize-growing regions in the developing world. Several factors, including high incidence of abiotic and biotic stresses, high irrigation costs, and inability of farmers to access and purchase good quality seeds and fertilizers, contribute to the low maize productivity (Beyene et al., 2015) [2].

According to (Musvosvi & Wali, 2017), the use of genetics to improve drought tolerance and provide yield stability is an important part of the solution to stabilizing global production. That is why the development of maize varieties with enhanced tolerance to drought stress and higher water use efficiency (WUE) has become a high priority goal for major breeding programs, both in the private and public sectors [3]. The breeding programs improve drought tolerance via diverse strategies such as recurrent selection and evaluation of segregating population under managed and multi-location drought-stress environment, use of secondary traits for selection under drought condition, genomic-based approach and transgenic technology. Understanding the nature of drought response in maize and some major strategies used for improving drought stress-tolerant maize lines will provide opportunities to improve the breeding process. Development of drought tolerant maize germplasm is critical to alleviate drought impacts on maize production. In breeding drought tolerant maize hybrids that would sustain production under climatic changes, identification of parents and knowing their attributes through characterization is a prerequisite.

Drought is the single most common cause of severe food shortage in developing countries and climate change is predicted to further exacerbate its impact [4]. It is also estimated that some 1.8 billion people will suffer from water shortage and two thirds of humanity will be affected by water stress by 2025 compromising cereal production sub Saharan Africa and Latin America. In maize, moisture stress is most devastating when it occurs at flowering with causing yield losses of 45-60%. In the tropics, annual maize yield losses due to drought are thought to average about 17% but can reach 80-100% depending on severity and timing of drought (Mhike, 2013).

Drought, like many other environmental stresses, has adverse effects on crop yield including maize *(Zea mays L.)*. Low water availability is one of the major causes for maize yield reductions affecting the majority of the farmed regions around the world. Therefore, the development of drought-tolerant lines becomes increasingly more important. In maize, a major effect of water stress is a delay in silking, resulting in an increase in the anthesis-silking interval, which is an important cause of yield failures (Sayadi Maazou, Tu, Qiu, & Liu, 2016) [5].

Conventional breeding has improved the drought tolerance of

***Corresponding author:** Bulo Debesa, Ethiopian Institute of Agricultural Research, Melkassa Agricultural Research Centre, P.O. Box 436, Adama Ethiopia, E-mail: bulodebesa2014@gmail.com

Received: 02-Nov-2023, Manuscript No: acst-23-121629, **Editor Assigned:** 05-Nov-2023, pre QC No: acst-23-121629 (PQ), **Reviewed:** 19-Nov-2023, QC No: acst-23-121629, **Revised:** 23-Nov-2023, Manuscript No: acst-23-121629 (R), **Published:** 30-Nov-2023, DOI: 10.4172/2329-8863.1000641

Citation: Debesa B, Ayalneh D, Habtemariam E, Mitiku T, Wendwesson T, et al. (2023) Review on Breeding Strategies for Drought Tolerance in Maize (*Zea mays L.*). Adv Crop Sci Tech 11: 641.

temperate maize hybrids and the use of managed drought environments, accurate phenotyping, and the identification and deployment of secondary traits has been effective in improving the drought tolerance of maize populations and hybrids as well [6]. The contribution of molecular biology identify key genes involved in metabolic pathways related to the stress response. Functional genomics reverse and forward genetics and comparative genomics are all being deployed with a view to achieving these goals. However, a multidisciplinary approach, which ties together breeding, physiology and molecular genetics, can bring a synergistic understanding to the response of maize to water deficit and improve the breeding efficiency (Sayadi Maazou et al., 2016).

The objective of this review will focus on the major strategies or approaches used by breeding programs for improving drought tolerance maize [7].

Literature Review

Biology of maize crop

Maize *(Zea mays L.)* belongs to the grass family (Gramineae) and is a tall annual plant with an extensive fibrous root system. It is a cross pollinating species, with the female (ear) and male (tassel) flowers in separate places on the plant. Maize stems resemble bamboo canes. The ears are female inflorescences, tightly covered over by several layers of leaves [8]. The apex of the stem ends in the tassel, an inflorescence of male flowers. When the tassel is mature and conditions are suitably warm and dry, anthers on tassel release pollen. Maize pollen is dispersed by wind; most pollen falls within a few meters of the tassel. The kernel of maize has a pericarp of the fruit fused with the seed coat, typical of the grasses. It is close to a multiple fruit in structure, except that the individual fruits never fuse into a single mass. The grains are about the size of peas, and adhere in regular rows. The grain develops in the ears or cobs often one on each stalk; each ear has about 300 to 1000 kernels, weighing between 190 and 300 g per 1000 kernels, in a variable number of rows (12 to 16).Weight depends on genetic, environmental and cultural practices [9].

Grain makes up about 42 % of the dry weight of the plant. The kernels are often white or yellow in colour, although black, red and a mixture of colures is also found. There are a number of grain types, distinguished by differences in the chemical compounds deposited or stored in the kernel (Sheikh et al., 2017).

Drought

Stress is defined as a factor that causes, through its presence or its absence, a reduction in plant grain yield termed meteorological drought, when precipitation is significantly below expectation for the time of year and location. Drought is a multidimensional stress affecting plants at various levels of their organization. Drought environments are characterized by wide fluctuations in precipitation, in quantity and distribution within and across seasons. The effect of stress is usually perceived as a decrease in photosynthesis and growth. It is believed that no other environmental factor limits global crop productivity more severely than water deficit (Gezahegn B.2005) [10, 11]

Types of drought and its effects on maize

Agricultural drought: Agricultural drought refers to the shortage of the sufficient water available for a crop at any given stage of its development resulting in impaired growth, wilting and ultimately reduced crop yields (Bänziger et al., 2006). This definition looks at the link between meteorological and/or hydrological droughts and agricultural impacts, and focuses more on the vulnerability of the crops at their different growth stages vis-à-vis plant-water needs. Drought affecting agriculture is the most prevalent abiotic stress which limits plant growth and productivity worldwide, with devastating socio-economic impacts (Jayne et al., 2010). It is a major cause of food insecurity for many households as it has been estimated to cause annual maize yield loss of 24 million tons in the developing world (FAOSTAT 2010; Edmeades 2008) [12].

Relevant definition of agricultural drought appears to be a period of dryness during the crop season, sufficiently prolonged to adversely affect the yield. The extent of yield loss depends on the crop growth stage and the degree of stress. Water stress is considered as one of the most devastating environmental stresses worldwide as it has rendered large area of agricultural land unproductive around the globe (Avramova et al., 2015; Huang et al., 2015; Langridge and Reynolds, 2015; Obidiegwu et al., 2015; Zhan et al., 2015) [13].

Alterations in rainfall pattern and rising temperature are major causes of drought and have contributed an appreciable decline in crop productivity (Lobell et al., 2011; Langridge and Reynolds, 2015; Obidiegwu et al., 2015). Consequently, considerable agriculture losses occurred because drought sensitive crops failed to grow under such conditions (Athar and Ashraf, 2009; Huang et al., 2015). It is more likely that increasing population and changing climatic conditions will increase water scarcity, which will cause a further decrease in crop productivity in the world. Therefore, concrete efforts are required to meet the increasing demand for food for heavily populated geographical areas with water scarcity. In order to achieve this target, it is imperative to understand how plants respond and adapt to water stress [14].

The inhibition of plant and root growth due to water stress is the earliest growth response, which reduce rate of transpiration thus help in water conservation. However, such effects can reduce the yield up to 60% of maize even if maize plants do not show leaf wilting (Ribaut et al., 2009). Among different plant adaptive strategies to water stress, drought avoidance is one of the most important drought adaptive strategies that can be used for enhancing crop yield under water stress conditions (Blum, 2011a). This can be achieved in a variety of ways, including adjustment of growth rate and growth pattern of shoot and root (Comas et al., 2013) [15].

Despite considerable significance of maize as food, forage and oil, a few studies have been focused on the selection of maize germplasm to appraise its drought or water stress tolerance (Avramova et al., 2015). One of the most plausible techniques to simulate uniform drought includes the use of metabolically inactive compound such as Polyethylene glycol (PEG) which has been widely employed by a number of workers to study the effects of water stress in different groups of plants (Ashraf et al., 1996; Kauser et al., 2006; Shamim et al., 2014) [16].

Important causes for agricultural drought are: inadequate precipitation, erratic distribution, and long, dry spells in the monsoon, late onset of monsoon, early withdrawal of monsoon, Lack of proper soil and crop management (Fayaz et al., 2017).

Westgate and Boyer (1986) compared the response of male and female reproductive tissues and found silk water potential to follow changes in leaf water potential, while pollen water potential with vegetative tissue. Using stem infusions of sucrose solution showed that the effects of drought at flowering could be partially alleviated; suggesting silk delay may be a symptom of limited assimilates supply rather than a primary cause of bareness. The delay in silking results in decreased male-female flowering synchrony or increased anthesis silking interval (ASI). (Bolaños and Edmeades, 1993a) [17].

Effects of drought on maize

Maize inflorescence consists of separate male and female flowers making it more vulnerable to drought stress during flowering time (Grant et al., 1989). Tassel development and pollen shed in maize are less sensitive to fluctuations in moisture availability compared to silk growth. The allocation of nutrients to ears, ovules and silks is reduced under drought as a result of the dominance effects of the apical tassel. Silk emergence in relation to male flowering is delayed when drought takes place just before flowering and this result in and increased anthesis silking interval (Bolanos and Edmeades, 1993a) [18].

When the anthes silking interval is lengthened the pollen might arrive when silks have dried up (Bassetti and Westgate, 1993) or after ovaries have used up their starch reserves (Saini and Westgate, 2000; Zinselmeier et al., 2000). This scenario results in retarded ear and silk growth and accelerated kernel and ear abortion (Edmeades et al., 1993). The maize crop has been found to be more susceptible to moisture stress one week before to two weeks after flowering (Grant et al., 1989). Grain abortion normally takes place during the first 2-3 weeks after the emergence of silks (Westgate et al., 1991). It is intensified by any stress that decreases canopy photosynthesis and movement of assimilates to the developing ear. This scenario results in the growing ear being deprived of the necessary nutrients (Stevens, 2008) [19].

Therefore, the amount of assimilates reduces to below threshold levels required to sustain grain development and growth (Edmeades and Tollenaar et al., 1992). The decrease in photosynthesis can be due to a decrease in radiation interception associated with increased leaf rolling (Bolanos et al., 1993). Reduction in photosynthetic rate decreases the volume of nutrients available for distribution to the sink organs. The amount of stress that drought imposes on the maize crop results in modifications of photosynthetic pigments and constituents. Maize is more vulnerable to drought compared to sorghum as a result of its shallow root system, enlarged leaf surface area, increased transpiration rate, slower grain development rate and extended grain filling period [20, 21].

Morphological changes

In the morphological changes, there are changes in the cell elongation, stimulation of cell division and alternation in cell differentiation status (Potters et al., 2007). So therefore, there is negative effect on the plant growth and development through the arrest of the cell cycle machinery (Peres et al., 2007). In plant tissues, water potential and content are maintained to increasing uptake or limiting loss, so they are in balance. So these balances are achieved by the morphological traits and their development, which is parallel to decrease the photosynthesis rate (Lawlor, 2002). So therefore decreasing the CO2 and water loss from the leaves will affect the mesophyll metabolism (Parry et al., 2002). In on long term, there is also root and shoot growth effects which leads to increased growth, tissue water storage capacity effect and therefore there is change in root growth to maximize water uptake are most crucial for crop plants (Verslues et al., 2006) [22].

Physiological changes

Maize is affected by drought during its entire life cycle with varying degrees of damage or loss to the ultimate yield. The impact of restricted water availability on crop performance is dependent on crop growth stage, crop history, leaf area, root volume, atmospheric vapour pressure deficit, temperature and radiation (Bänziger et al., 2000). Maize is comparatively more susceptible to drought than its close relative sorghum, because of its flowering architecture that predisposes developing grain to environmental stresses (Grant et al., 1989) [23]. Moisture stress occurring soon after planting results in poor germination, reduction in plant population and consequently yield. Plant growth from emergence to V8 (eighth leaf fully emerged or about 4 weeks after planting) determines the plant and leaf size affecting assimilates supply at grain filling (Monneveux and Ribaut, 2006) Maize is particularly sensitive to water stress occurring just before and during flowering when the crop's yield potential is defined (Malosetti et al., 2008). The flowering period is the most crucial stage in terms of negative effects of drought on yield. During this stage, one day of water stress can potentially decrease yield by up to 22% (Landi et al., 2007). Silking or the onset of the reproductive stage is the most sensitive stage and water stress during this period coupled with high temperatures can result in 100 percent yield loss since daytime temperatures can kill pollen before it can reach the silks (Banziger et al.,2006) . When water stress occurs just before flowering, a delay of silk emergence in relation to male flowering is observed increasing anthesis-silking interval (ASI) which is correlated with lower yield (Bolanos and Edmeades, 1996). When ASI is lengthened the pollen may arrive when silks have withered or senesced or after ovaries have exhausted their starch reserves (Saini and Westgate, 2000). At flowering extreme sensitivity is confined to the period-2 to 22 days after silking with the peak at 7 days. Complete bareness can occur if maize plants are water stressed just before tassel emergence to the beginning of grain filling (Bänziger et al., 2000) [24].

Thus, mid-season drought spells are critical as they coincide with the flowering period hence the need for genetic improvement of maize to better tolerate moisture stress at this crucial growth stage. Under moisture stress, apical (tassel) dominance is enhanced decreasing allocation of assimilates to cobs, ovules and silks resulting in reduced cob and silk growth rate and increased kernel and ear abortion (Bolanos et al., 1993). Under drought conditions, abscisic acid production increased inhibiting photosynthesis through stomatal closure and further decreasing assimilates supply (Bänziger et al., 2000). Starch metabolism is als inhibited with the enzyme invertase inhibited and reducing starch supply to ovaries or affected pollen (Kulwal et al., 2011). Water stress during grain-filling increases leaf senescence, shortens the grain-filling period, increases stem and root lodging and lowers kernel weight. Moisture stress during grain filling, results in incomplete filled kernels and reduced assimilate fluxes to growing organs causing kernel abortion (Messmer, 2006). This bareness may lead to complete loss of grain yield. Grain abortion is highest during the first 2-3 weeks after silking and is as a result of accelerated lower leaf senescence (Schussler and Westgate, 1995). In general, kernels near the ear tip are the last tobe fertilized, are less vigorous and most susceptible to abortion under water stress conditions. In addition under water stress lodging occurs because most stalk carbohydrate reserves are mobilised to the grain (Bänziger et al., 2002) [25, 26]

Mechanisms of drought response

When faced with drought stress, the plant species, environment, and the timing and intensity of the drought determine the type of response. Plants use four major categories of mechanisms in response to drought stress, namely drought escape, drought avoidance, drought tolerance, and drought recovery (Fang, Y et al., 2015). Drought escape involves adjustment of rate of maturity, rapid phenological development, developmental plasticity and remobilization of assimilates in order to escape dry seasons Turner, N.C (1979). This enables plants to complete their life cycle before the onset of severe drought stress [27].

In a drought avoidance strategy, a plant maintains fundamental normal physiological processes under mild or moderate drought stress by adjusting morphological structures or growth rates to reduce transpiration or sustain water uptake to keep water levels high within the plant Turner, N.C (1979). Such adjustments may include reduction in water losses such as through stomatal closure, leaf rolling and increased wax accumulation on the leaf surface Drought can also be avoided through enhanced water uptake by root modification or through increasing/decreasing the rate of development from vegetative to reproductive stages (Khan, Sovero, & Gemenet, 2016) [28].

In some cases, plants use a drought tolerance mechanism, which implies maintaining plant health and productivity despite low internal water potential, involving the regulation of hundreds of genes and series of metabolic pathways in order to reduce and/or repair the damage resulting from drought stress, which in turn enables a plant to sustain a certain level of physiological activities under severe drought stress Blum A and Luo J (2010). Drought avoidance and drought tolerance mechanisms can be referred to together as drought resistance, as the ability of a plant to live, grow and reproduce satisfactorily with limited and irregular water supply or under periodic water deficit conditions (Figure 1) [29].

Breeding met HODS for drought tolerance in maize

Among abiotic stresses, breeding for drought tolerance is one of the most challenging endeavours, because selected germplasm ought to perform exceptionally well not only under drought stress but also under optimum conditions. Since water is a scarce resource, improving varieties for drought tolerance is an important approach in reducing this problem. It is important in breeding for drought tolerance to consider breeding for other stress factors as well (Beebe et al., 2008).

Progress in breeding for drought tolerance has been slow as a result of the complex nature of the trait and an improved understanding of the fundamental mechanisms of drought would hasten progress in breeding for the trait (Ribaut et al., 2002).In an effort to improve maize productivity, maize breeders have exerted enormous efforts to breed hybrids with drought tolerance (Bruce et al., 2002). The efficiency in selection of germplasm for drought tolerance can be improved through use of managed drought environments. This can be done during the off-season (winter) with the use of controlled irrigation whereby the occurrence, extent and amount of drought stress on the crop are controlled (Banziger et al., 2000) [30].

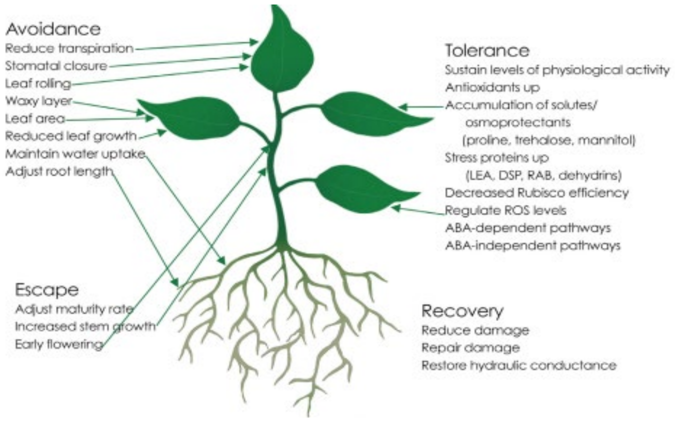

Figure 1: Plant responses to drought stress is complex can be categorized into four broad types: drought escape, drought avoidance, drought tolerance, and drought recovery, each characterized by interacting mechanisms. Mechanisms more closely linked to a category are shown, but are often part of other categories at the same time.

Although progress in drought tolerance can be achieved through conventional selection methods, trials must usually be replicated across a large number of locations and across several years before the expression of the trait can be conclusively identified. Grain yield is considered the primary trait for selection under drought stress conditions. Nonetheless, reduced heritability and variance of yield components make selection based only on grain yield inefficient (Stevens, 2008).

Suitable secondary traits used in selection for drought tolerance

Appropriate secondary traits selected for under drought stress should be genetically related to grain yield, have high heritability estimates, be consistent and easy to select for and not too expensive. These traits must furthermore be measurable at or before flowering so that undesirable parents are selected against and these traits should not be accompanied by yield loss under optimum environments (Edmeades et al., 1998). Critical secondary traits under drought identified at CIMMYT and Pioneer Hi-Bred include reduced prolificacy, anthesis silking interval, stay green and to a lesser extent leaf rolling (Banziger et al., 2000). Anthesis silking interval is measured as the number of days between silk emergence and pollen shedding and increases under drought stress as a result of retarded ear and silk growth (Bolanos and Edmeades, 1993b). Work done at CIMMYT has revealed that the heritability estimate for anthesis silking interval is related to or greater than the heritability for grain yield. A high negative correlation of anthesis silking interval with grain yield and other related traits such as kernel number and number of ears per plant has been reported. Anthesis silking interval and ears per plant have been widely used in breeding for stress tolerance in maize (Bolanos and Edmeades, 1993b; Banziger et al., 2000). These two traits have shown good genetic variability under drought stress conditions and high heritability [31].

The variation in number of kernels has a major effect on maize grain yield under drought (Bolanos and Edmeades, 1996). Bolanos and Edmeades (1993a) observed a 90% drop in yield as anthesis silking interval increased from-0.4 to 10 days, whilst Du Plessis and Dijkhuis (1967) reported 82% drop in grain yield as anthesis silking interval increased from 0-28 days. In genotypes selected for short anthesis silking intervals and increased grain yield under drought the bulk of the carbohydrates are channeled towards development of the ear and less towards the growth of tassels and vegetative organs (Edmeades et al., 1993). In tropical maize gains in selection have been linked with improved synchronization in silking and pollen shedding, reduced barreness, reduced tassel size, increased harvest index, delayed leaf senescence and reduced root length density in the upper soil profile with no alterations in water uptake or biomass (Bolanos and Edmeades, 1993a; b; Bolanos et al., 1993; Chapman and Edmeades, 1999).

Genotype x environment interaction (GEI)

The phenotype of an organism is a product of the interaction of its genotype and the environment (Falconer and Mackay, 1996). Environmental factors such as locations and seasons may have positive or negative impacts on a genotype. This association between the environment and the phenotypic expression of a genotype constitute the genotype by environment interaction (GEI) (Bondari, 2003). The crossover interaction is the most important in crop improvement as it results in change in magnitude and rank (Banziger and Cooper, 2001). Occurrence of GEI complicates selection of superior genotypes for environments. This is as a result of confounding effects of the three components of interaction between genotype and environment, namely genotype x location (G x L), genotype x year (G x Y) and genotype

Citation: Debesa B, Ayalneh D, Habtemariam E, Mitiku T, Wendwesson T, et al. (2023) Review on Breeding Strategies for Drought Tolerance in Maize (*Zea mays L.*). Adv Crop Sci Tech 11: 641.

x location x year (G x L x Y). The genotype environment interaction plays a significant role in relative performance of different varieties in different environments hence stability estimates depend considerably not only on choice of test location but also on choice of genotype (Falconer and MacKay, 1996; Simic et al., 2001).

Managed drought

According to (Banziger et al., 2000), managed drought stress screening is usually done off-season (winter) with the use of irrigation. Drought stress on genotypes is induced either at flowering or at grain filling stage. At intermediate stress level average grain yield is targeted to reduce by 15-30% of yields expected under optimum conditions and the stress will be targeting grain filling. A yield reduction of 30-60% of yields realized under optimum conditions is targeted for severe stress levels and the stress affects both flowering and grain filling. Under severe stress, irrigation is scheduled such that drought stress coincides with anthesis and silk emergence, but supplementary irrigation is applied 14 days after the end of pollen shedding in order to facilitate adequate grain filling of the formed grain. In intermediate stress, drought stress is timed to coincide with grain filling. It is important to ensure that irrigation is uniformly applied before onset of stress as this will result in stress levels being uniform in all genotypes, more constant plant performance and eventually improved breeding progress.

Managed drought screening at early breeding stage, careful and uniform management of timing and intensity of drought stress during selection, and use of secondary traits in addition to grain yield, resulted more in significant larger selection gains under random stress conditions than those expressed by equivalent genotypes selected through multi-location testing (Tsonev et al., 2009).

Agronomic interventions

According to Fayaz et al., (2017), improved crop management methods can complement the use of drought tolerant hybrids and contribute significantly to increasing and stabilizing yields under rain fed conditions or under irrigation where water supply is limited. Ensuring that planting densities are optimal, tillage is minimal, weeds are controlled and adequate fertilizer is applied at the right growth stage all increase water use efficiency (WUE). Water supply to the crop can be increased by water harvesting methods and the use of mulch. Where irrigation is in short supply, deficit irrigation, or the application of water at less than the potential evapotranspiration rate, can increase WUE at little cost to yield. Partial root drying, where dry and wet regimes are alternated under irrigation to reduce water applied can elicit a drought adaptive response and may save up to 25% of the water normally applied.

Breeding strategies

Maize is the most world grown crop in the Africa, America and Asia etc. Hybrid maize, because of its high grain yield as a result of heterosis (hybrid) is preferred by farmers over conventional varieties. When a region notes a deficiency in its water supply then a drought condition occurs. This occurs when a region receives consistently below average precipitation. It can have a substantial impact on the ecosystem and agriculture of affected region. Drought is important due to instability of national maize grain yields and of food supply and economy of small-scale maize based farming systems in the tropics. Water shortage affect maize yields throughout the crop cycle, but most severely at flowering and to a lesser degree at establishment. There are some techniques which are used to improve maize in drought tolerance conditions; such as Improvement of drought tolerance through Conventional Breeding and Molecular breeding approaches (Fayaz et al., 2017).

Improvement of drought tolerance through conventional breeding

Selection for yield and yield stability has been at the core of most maize breeding programs. The significant breeding gains in maize under drought stress is mainly attributed to the use of rainfed breeding nurseries with high plant densities and large scale multi-location testing (Tsonev et al., 2009). Improvement in the drought breeding methodology by using more severe drought stressed conditions imposed at different stages of development, led to increase of breeding progress under flowering drought to about 2.0-2.5% year-1 as compared to plants under unstressed conditions (Tsonev et al., 2009).

Population improvement for drought tolerance

Improvement in drought tolerance maize on flowering stage in CIMMYT (International Maize and Wheat Improvement Center) is using recurrent selection to improve under drought tolerance condition. So in this way, the grain yield of maize increased between 3.8% and 12.6% (Edmeades et al., 1999; Bolanos and Edmeadas, 1993a). Due to this, there is an increased the EPP (Ear per plant) and HI (Harvest Index) and reduce the ASI (Anthesis-silking interval), leaf senescence, plant height, stem biomass, time to anthesis and tassel primary branch number, and a small but significant increase in grain yield, EPP (Ear per plant), kernel weight per fertile ear and individual kernel weight was also be achieved under WW (well-water) conditions (Westgate, 1997). Increase the yield of grain in drought tolerance has improved in the specific conditions and low fertility conditions, two common adaptive stress involved (Bänziger et al., 1999). A common genetic basis between drought tolerance and better performance under low N conditions has been confirmed through QTL analysis and QTL common for both abiotic stresses were identified for ASI (Anthesis silking interval) and EPP (Ear per plant) (Ribaut et al., 2007).

Hybrid improvement for drought tolerance in maize

To improve the hybrid seed for drought tolerance, the seed industry has succeeded in efficient testing to improve mechanization and imposing high selection intensities (Coors, 1999). These hybrid evaluations are designed as such to maximize the adaptation and stability under different environment cultural practices such as planting density, planting date, drought stress, fertilizer input, tillage and crop rotation etc.; climatically and edaphically. Most of recent improvement in hybrid performance is due to a greater tolerance to abiotic stress, particularly in situations where high planting densities are used (Device et al., 2004; Tollenaar and Wu, 1999) [32].

Stress management

Timing, intensity, and uniformity of the stress are factors to consider in stress management. Timing should be such that the growth stages targeted are susceptible to the stress, have a high probability of being affected by that stress in the target environment, and involve tolerance related traits that can be modified through breeding. Stress intensity should be severe enough so that traits become important for yield distinct from those which affect yield under non stressed conditions. If the stress is uniform over space and time, genetic differences will be easier to observe and progress will be greater (Fayaz et al., 2017).

Secondary traits that help to identify drought tolerance

Secondary traits are those other than economic yield itself which can provide a measure of plant performance. An ideal secondary trait genetically correlated with grain yield in the target environment, genetically variable, have a high level of heritability, be simple, cheap, non-destructive and fast to assay, be stable throughout the measurement period and would not be associated with any yield loss under non-stressed conditions. Under drought stress conditions, breeding progress is impeded by a significant level of G × E (both with respect to cropping season and location). Given the poor heritability of grain yield under drought stress conditions, genetic progress is hard to achieve via direct selection. However, because under drought, both the heritability (h2) of at least some secondary traits remains high and the genetic correlation between grain yield and these traits increases significantly, recourse to indirect selection becomes an attractive strategy. Selection based on secondary traits which reflect the direct effects of drought can improve the response, since it avoids the confounding effects of other stresses, such as poor soil fertility, micronutrient deficiency and pathogen presence. Application of this strategy has generated genetic gains under a range of environmental conditions (Sayadi Maazou et al., 2016) [33].

Selection and evaluation of segregating population under managed and multi-location drought-stress environments

The choice of a selection strategy is critical to breeding for stress tolerance. Probably the most widely used strategy is to select for yield under non-stressed conditions, and then evaluate those selections at many sites with variable moisture availability or “random stress. Underlying assumptions of this approach are that genes for drought tolerance are present in elite high yielding material, even after the number of genotypes has been narrowed to the few evaluated under random stress, and that selection under optimum growing conditions can also increase performance in sub-optimum conditions. Moreover, hybrids usually yield better than varieties under drought with heterosis acting as an important source of stress tolerance (Sayadi Maazou et al., 2016).

The choice of the testing environment(s) is critical to the rate of achievable genetic gain. Ideally, the selection environment should mirror the target environment in rainfall distribution, physical and chemical soil properties, water distribution profiles and potential evapotranspiration rates, otherwise significant genotype × environment (G × E) interactions result in much of the gain achieved in the selection environment not being reproduced in the target environment. Multi-location evaluation is necessary to estimate the importance of G × E. It is especially critical in the context of breeding for drought tolerance, where a consequence of lowered plant vigor is a higher responsiveness to environmental variation. (Sayadi Maazou et al., 2016) [34].

Molecular breeding approaches

The marker-assisted recurrent selection (mars) approaches: MAS involves the use of molecular markers that map close to specific genes or quantitative trait loci (QTLs), whose association with the target trait has been established and can be used to select individuals with favorable alleles. Reliable, accurate and high-throughput trait evaluation and dense molecular markers across the genome can either be used to identify marker-trait associations via QTL mapping or genome-wide association mapping approaches. Based on these methods, QTLs for traits associated with drought resistance have been identified in important crops such as maize, rice, wheat, soybean, sorghum, foxtail millet, pearl millet, among other crops. However, many drought-related QTLs identified are not stable in different environments. A QTL can have positive or negative additive effects, depending on the drought condition due to strong genotype-by-environment interaction (G x E). Thus, there is real need to first define the target drought scenario for drought resistance QTL identification. Monsanto developed genotyping systems and information tools that allowed molecular marker-assisted methodologies to increase mean performance of elite breeding populations in maize (Khan et al., 2016).

The advantage of MARS is higher as compared to phenotypic selection, although the use of MARS has enjoyed only in public sector, only limited success in public sector (Ragot et al., 2000; Johnson, 2004; Crosbie et al., 2006). For example, (Ragot et al., 2000) identify QTL in bi parental maize population and then applied a genetic index where is involving agronomic performance (grain yield, and moisture at harvest) and adapted to abiotic stress (early vigor under cold conditions). Similarly, other scientist (Eathington et al., 2005) demonstrated that the rate of genetic gain achieved through MARS was about twice that possible using in the phenotypic selection. So there are several accounts in which at least one of parental lines of commercial maize hybrids was derived via MARS.MAS for drought-related traits based on genetic mapping information should preferably target major QTL with a considerable effect, consistent across germplasm and with a limited interaction with the profile of water availability. In maize, however, QTL studies in the past have not identified any QTL with sufficiently large effects to be effectively used in MAS programs.

Genomic based approach

Genomic selection incorporates all the available marker information into a model to predict genetic values of breeding progenies for selection (Beyene et al., 2015).

Drought tolerance is a complex quantitative trait controlled by many genes, and is one of the most difficult traits to study and characterize. Compared to conventional approaches, genomics offers unprecedented opportunities for dissecting quantitative traits into their single genetic determinants, the so-called quantitative trait loci (QTL), thus paving the way to marker-assisted selection (MAS) and, eventually, cloning of QTLs and their direct manipulation via genetic engineering.

Therefore, it is possible to identify major QTLs regulating specific drought responses and it will provide an efficient way to improve drought tolerance in maize germplasm. The increasing number of studies reporting QTLs for drought-related traits and yield in drought stressed crops indicates a growing interest in this approach (Sayadi Maazou et al., 2016). In fact, using a modeling approach combined with field measurements, Ribaut et al. identified a common QTLs for both leaf growth and ASI in a recombinant inbred line population evaluated under water stress conditions (Sayadi Maazou et al., 2016). For all common QTL the allele conferring high leaf elongation rate conferred a short ASI, indicating a high silk elongation rate. They also observed unsurprisingly that drought-related QTL are dispersed throughout the maize genome. In another study, Sari-Gorla et al. performed a linkage analysis between the expression of male and female flowering time, ASI, plant height and molecular markers (Sayadi Maazou et al., 2016).

Transgenic technology

Traditional breeding techniques contribute considerably to the popularization and application of drought-resistant lines and cultivars, but the limitations are the long breeding cycle and the extensive time consumption. Thanks to rapid progress in bio-technology and genome sequencing, there is now a diverse choice of tools for the identification of candidates for genes involved in specific processes, including the response to drought. (Sayadi Maazou et al., 2016).

Transgenic sources of new variation for these traits will likely be

Table 1: List of drought tolerant variety released under Ethiopian institute of agricultural research.

Name of Variety	Protein quality	Type of variety	Year of release	Days to maturity	Grain yield qt/ha	
					Research station	On farm
Melkass1	Non QPM	OPV	2000	90	35-45	25-35
Melkassa2	Non QPM	OPV	2004	130	55-65	45-50
Melkassa3	Non QPM	OPV	2004	125	50-60	45-50
Melkassa4	Non QPM	OPV	2006	105	40-50	35-40
Melkassa5	Non QPM	OPV	2008	125	35-45	30-35
Melkassa6Q	QPM	OPV	2008	120	45-55	30-40
Melkassa7	Non QPM	OPV	2008	115	45-55	30-40
MH130	Non QPM	Hybrid	2012	120	55-65	45-50
MH138Q	QPM	Hybrid	2012	140	75-80	55-65
MH140	Non QPM	Hybrid	2013	140	85-95	65-75

*OPV Open pollinated variety,QPM Quality protein maize.
Source:Progress report from Melkassa research center.

required, along with a careful physiological evaluation of the whole plant effects of such transgenes. Multiple genes contained in single constructs allow for efficient stacking of traits. Small RNA fragments are emerging as powerful control elements of stress response in plants (Fayaz et al., 2017).

Current achievements of breeding for drought tolerant maize varieties in Ethiopia

Currently in Ethiopia different maize varieties which gives significance yield under drought prone areas has been released. The following open pollinated varieties and hybrid varieties were released by Melkassa Agricultural research center of Ethiopian Institute of agricultural research (Table 1).

Future prospects of drought tolerant maize breeding in Ethiopia

Currently Maize research program of Ethiopian institute of agricultural research is conducting maize research program in three maize growing agro ecologies. These were, Mid altitudes of Bako national maize research program, Highland maize research project of Ambo Agricultural research center and Melkassa research center of low moisture and heat stress areas. However, Melkassa research center is responsible for introducing and generating drought tolerant maize varieties. A number of research activities particularly development of inbred lines, hybridization, introduction and evaluation of drought tolerant maize OPVs and hybrids from international research institution is going on and promising genotypes were testing along low moisture and heat stressed areas of Ethiopia. Strong linkage with international well known research institutes has taken as an opportunity to escalate drought tolerant maize variety development in Ethiopia.

So far,about 11 drought tolerant maize varieties which were released for moisture stressed areas of Ethiopia was not as such satisfies small scale farmers and seed companies to produce enough amount of seed due to low productivity of the crop. So that, it implies that it needs hard working and more technology generation to produce high yielding variety under drought stressed conditions. Testing of transgenic drought tolerant maize hybrid has been launched in Ethiopia which creates more opportunity in promoting and generating drought tolerant hybrids [35].

Summary and Conclusions

In conclusion, conventional breeding has improved the drought tolerance of temperate maize hybrids and the use of managed drought environments, accurate phenotyping and the identification and deployment of secondary traits has been effective in improving the drought tolerance of tropical maize populations and hybrids.

The contribution of molecular biology identify key genes involved in metabolic pathways related to stress response e.g., the factors involved in kernel development. Armed with better understanding of the physiological mechanisms and the genetic basis of the response of maize to drought, it should become increasingly feasible to identify, transfer and select key genes and alleles to build genotype with much improved tolerance to drought.

It is only recently that carefully selected or managed abiotic stress screening approaches have been more widely used for assessing the stress tolerance of crop genotypes. Simultaneous selection for tolerance and resistance to abiotic and biotic stresses, while also monitoring performance under high potential conditions, can result in significant breeding progress in target environments where combinations of those stresses occur and particularly at lower yield levels.

While assessing the effectiveness of various selection conditions for breeding progress in the target environment is inherently difficult, as large and long-term breeding investments are involved, breeders may have been too concerned with keeping heritability high while ignoring the need to adequately representing the target environment during selection.

Managed stress screening approaches provide an opportunity to keep heritability high and adequately representing abiotic stress factors that are relevant in the target environment. It is desirable that more breeding programs use high-priority abiotic stresses in their mainstream breeding program, so that more experience on breeding approaches that effectively target stress environments can be gained. Such insights are particularly relevant for breeders in low income countries that target production conditions that are stressed due to both biophysical and socio economic reasons.

Multidisciplinary approach, which ties together breeding, physiology and molecular genetics, can bring a synergistic understanding to the response of maize to water deficit and improve the breeding efficiency.

References

1. Athar HR, Ashraf M (2009) Strategies for Crop Improvement against Salinity and Drought Stress: An Overview. In Salinity and Water Stress Improving Crop.
2. Avramova V, AbdElgawad H, Zhang Z, Fotschki B, Casadevall R, et al. (2015) Drought induces distinct growth response, protection, and recovery mechanisms in the maize leaf growth zone. Plant physiology 169: 1382-1396.

3. Ayalew H, Xuanli Ma, Guijun Yan (2015) Screening wheat (Triticum spp.) genotypes for root length under contrasting water regimes: potential sources of variability for drought resistance breeding. Journal of Agronomy and Crop Science 201.3: 189-194.
4. Bänziger M, Edmeades GO, Lafitte HR (2006) Selection for drought tolerance increases maize yields over a range of N levels. Crop Sci 39: 1035-1040.
5. Bänziger M, Setimela P, Hodson D, Vivek B (2006) Breeding for improved abiotic stress tolerance in maize adapted to southern Africa. Agriculture Water Management 80: 212-224.
6. Bernado R (2009) Genome-wide selection for rapid introgression of exotic germplasm in maize. Crop Science 49: 419-425.
7. Beyene, Yoseph (2015) Genetic gains in grain yield through genomic selection in eight bi-parental maize populations under drought stress. Crop Science 55.1: 154-163.
8. Blum A (1988) Osmotic adjustment and growth of barley genotypes under drought stress Agronomy Volume 29: 230-233.
9. Blum A (2011a) Drought resistance-is it really a complex trait? Funct. Plant Biol 38: 753 757.
10. Bolanos J, Edmeades GO (1996) The importance of anthesis silking interval in breeding for drought tolerance in tropical maize. Field Crops Research 48: 65-80.
11. Bolaños J, Edmeades GO, Martinez L (1993) Eight cycles of selection for drought tolerance in lowland tropical maize. III. Responses in drought-adaptive physiological and morphological traits. Field Crops Res 31: 269-286.
12. Bolaños J, Edmeades GO, Martinez L (1993b) Eight cycles of selection for drought tolerance in lowland tropical maize. III. Responses in drought-adaptive physiological and morphological traits. Field Crops Res 31: 269-286.
13. Bolanos J, Edmeades GO, Martinez L (1993) Eight cycles of selection for drought tolerance, in lowland tropical maize. III. Responses in drought adaptive physiological and morphological traits. Field Crops Research 31: 269-286.
14. Bondari K (2003) Statistical Analysis of Genotype x Environment Interaction in Agricultural Research. Experimental Statistics Coastal Plain University of Georgia Tifton GA 31: 733-748.
15. Campos H, Cooper M, Habben JE, Edmeades GO, Schussler JR, et al. (2004) Improving drought tolerance in maize: a view from industry. Field Crop Res 90: 19-34.
16. Comas, Louise H (2013) Root traits contributing to plant productivity under drought. Frontiers in plant science 4: 442.
17. Edmeades GO (1995) Recent evaluations of progress in selection for drought tolerance in tropical maize. Proceedings of the 4th Eastern and Southern African Regional Maize Conference 28.
18. Grant RF, Jackson BS, Kiniry JR, Arkin GF (1989) Water deficit timing effects on yield components in maize. Agronomy journal 81: 61-65.
19. Hoisington D, Khairallah M, Reeves T, Ribaut JM, Skovmand B, et al. (1996) Plant Genetic Resources: What Can They Contribute Toward Increased Crop Productivity. Proceedings of the National Academy of Sciences of the United States of America, 96, 5937-5943.
20. Huang Q, ZhaoY, Liu C, Zou X, Cheng Y, et al. (2015) Evaluation of and selection criteria for drought resistance in C hinese semiwinter rapeseed varieties at different developmental stages. Plant Breeding 134: 542-550.
21. Kauser R, Athar HUR, Ashraf N (2006) Chlorophyll fluorescence: A potential indicator for rapid assessment of water stress tolerance in canola (Brassica napus L.). Pak J Bot 38: 1501-1509.
22. Kulwal PL, Thudi M, Varshney RK (2011) Genomics interventions in crop breeding for sustainable agriculture.
23. Landi P, Saungineti MC, Liu C, Li Y, Wang TY, et al. (2007) Root ABA1 QTL affects root lodging, grain yield and other agronomic traits in maize grown under well watered and water stressed conditions. Journal of Experimental Botany 58: 319-326.
24. Lobell D, Schlenker W, Costa-Roberts J (2011) Climate trends and global crop production since 1980. Sci 333: 616-620.
25. Malosetti MJ, Ribaut J, Vargas M, Crossa J, van Eeuwijk F, et al. (2008) A multi-trait multi environment QTL mixed model with an application to drought and nitrogen stress trials in maize *(Zea mays L.)* Euphytica 161: 241-257.
26. Messmer RE (2006) The genetic Dissection of Key factors Involved in the Drought Tolerance of Tropical Maize *(Zea mays L)* PhD Thesis ETH Swizz Federal Institute of Technology Zurich.
27. Monakhova OF, Chernyadev P (2002) Protective role of Kartolin 4 in wheat plants exposed to soil drought. Applied Biochemistry and Microbiology 38: 378-380.
28. Moneo M, Iglesias A (2004) Food and Climate; Types of Droughts. Goddard Institute of Space Studies USA
29. Moneo M, Iglesias A (2004) Food and Climate; Types of Droughts. Goddard Institute of Space Studies USA
30. Monneveux P, Ribaut JM (2006a) Secondary traits for drought tolerance improvement in cereals. pp 97-143.
31. Mutasa M (2010) Zimbabwe's Drought Conundrum: Vulnerability and Coping in Buhera and Chikomba Districts. MSc Degree in Development Studies Thesis Norwegian University of Life Science. Oslo Norway.
32. Parry MAJ, Flexas J, Medrano H (2005) Prospects for crop production under drought: research priorities and future directions. Annual Applied Biology 147: 211-226.
33. Sheikh FM, Dar ZA, Sofi PA, Lone AA (2017) Rcent advances in breeding for abiotic stress (drought) tolerance in Maize. Int J Curr Microbiol App Sci 6: 2226-2243.
34. Tsonev S, Todorovska E, Avramova V, Kolev S, Abu-Mhadi N, et al. (2009) Genomics assisted improvement of drought tolerance in maize: QTL approaches. Biotechnology and Biotechnological Equipment 23: 1410 1413.
35. Zhang J, Schurr U, Davies WJ (1987) Control of stomatal behavior by abscisic acid which apparently originates in the roots. J Experimental Botany 38: 1174-1181.