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Review Paper

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THE IMPACTS OF DROUGHT STRESS ON CROP PRODUCTION AND PRODUCTIVITY

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ABSTRACT

Water stress due to drought is probably the most significant abiotic factor limiting plant and also crop growth and development. This paper reviewed the effect of drought stress on crop production from morphological to molecular levels, Drought resistance in crop plants, and managing drought stress by production of appropriate plant genotypes together with the adjustment of agronomic practice with the objectives; to review the impacts of drought stress on crop production and possible breeding method to improve crop response and to review different drought management mechanism of the crop. The effect of drought on yield is highly complex and involves processes as diverse as reproductive organs, gametogenesis, fertilization, embryogenesis, and seed development. Drought-induced yield reduction has been reported in many crop species, which depends upon the severity and duration of the stress period. Water stress during vegetative or early reproductive growth usually reduces yield by reducing the number of seeds in soybean and canola, Inmaize, water stress reduced yield by delaying silking, thus increasing the anthesis-to-silking interval. Plant drought tolerance can be managed by adopting strategies such as mass screening and breeding, marker-assisted selection and exogenous application of hormones seed priming osmoprotectants and using silicon tossed or growing plants, as well as engineering for drought resistance. Identification of drought-related quantitative trait loci (QTLs) coupled with marker-assisted selection has shown some positive results. Transgenic technologies promise to make progress in breeding for drought tolerance through a more fundamental understanding of underlying mechanisms of drought tolerance and identifying potential candidate genes. These new approaches provide opportunities to direct the continued breeding strategies of genotypes giving stable yields under drought stress.

KEYWORDS

Abiotic stress, Drought Resistance, MAS, Osmoprotectant,, Seed priming, Transgenic, Yield loss.

1 INTRODUCTION

The crop growth and development are constantly influenced by environmental conditions such as stresses which are the most important yield reducing factors in theworld[1].Stress is defined as any soil and climatic conditions or combination of both that hinders the full realization of genetic potential of a plant, limiting their growth, development, and reproduction. These effects in plants of agricultural interest have a major impact on productivity and quality and thus represent together with biotic stress, the cause of the gap between yield potential and actual production[2]. The changes in climate forecasted for the near future are expected to exacerbate the onset and magnitude of events of stress due to increased drought and erratic rain fall and rise of evapotranspiration rates due to growing temperatures.

The efforts in meeting the food requirements on sustainable basis for ever increasing population are seriously being hampered due to biotic and abiotic stresses. Abiotic factors (like drought, salinity and temperature), are most important accounting for about 70% reductions in yield of our cereal crops[3]. Agriculture scientists are facing the challenge of drought in the current situation of water shortage that may affect negatively the arable area. The simplest definition of drought in the context of agriculture is a situation when the water availability to plant is less than what is required to sustain its growth and development[4]. Drought tolerance is the ability of the plant to survive in water limited conditions [5]. However, inducing drought tolerance in crop plants is not a simple task rather one of the most difficult challenges currently the breeders face. This is due to its polygenic nature with low heritability and high G × E interactions [6]. Drought is a major yield limiting factor badly affecting the crop productivity worldwide[7]. It is a meteorological term and takes place when there is more moisture loss from soil surface and fewer water supplies to soil in the form of rainfall or other sources of precipitation. Accordingto[8], Moisture stress is a limiting factor for crop growth in rid and semi-arid regions due to low and uncertainty precipitation. Water stress due to drought is probably the most significant abiotic factor limiting plant and also crop growth and development. During the drought, conditions water potential and turgor are decreased and this situation disturbs the normal functioning of plant body and dangerous for arable field crops growth and subsequently for food security[9].

Drought occurs every year in many parts of the world, often with devastating effects on crop production[10]. Worldwide losses in crop yields from drought stress probably exceed the losses from all other abiotic stresses combined[11]. Because water resources for irrigating crops are declining worldwide, the development of more drought-resistant or drought-tolerant cultivars and greater water-use efficient crops is a global concern [12]. In the last several decades, the most productive agricultural regions were exposed to drought stress in most years and in occasional years with severe drought. Commonly, drought stress synchronizes with extreme temperature, leading to even greater severity of drought stress[13]. Drought stress affects crop growth and yield during all developmental stages.

The effect of drought on yield is highly complex and involves processes as diverse as reproductive organs, gametogenesis, fertilization, embryogenesis, and seed development[14]. Reproductive development at the time of flowering is especially sensitive to drought stress[15]. Therefore, an understanding of how are productive process affected by drought is of particular interest for improving drought tolerance[16]. During flowering early crop yield potential, i.e. the number of grains per land area, is determined. Final crop yield is primarily determined by resource availability and the number of grains is adjusted in the plant to match the resource-defined yield level[17]. Manipulation of flowering time might also have considerable significance as a management tool to avoid yield reductions that might commonly occur from drought stress during anthesis in a growing region[18].

Currently selection criteria are applied for good variety selection as compare to breeding techniques, which are time consuming[19]. Drought stress or water deficit stress is globally renowned feature of climate, also an alarming threat to our agriculture that could be unavoidable. Water is an integral part of plant body plays an important role in growth initiation, maintenance of developmental process of plant life and hence has pivotal functions in crop production.[20] reported the solid drought effect on growth in experiment done in glass house and concluded that genetic makeup of maize show variation in drought tolerance and is better manipulated under severe conditions of drought. Responses to drought are species specific and often genotypespecific[21]. Moreover, the nature of drought response of plants is influenced by the duration and severity of water loss[22], the age and stage of development at the point ofdroughtexposure[23]. As well as the organ and cell type experiencing water deficits[24]. *This review paper comprises an overview of research works reported on the effect of drought stress on crop production from morphological to molecular levels, drought resistance in crop plants, and managing drought stress by production of appropriate plant genotypes together with adjustment of agronomic practice with the objectives of; to review the impacts of drought stress on crop production and possible breeding method to improve crop response and to review different management strategies that helps to develop drought resistant genotypes.*

2. LITERATURE REVIEW

2.1 Effects of drought stress on crop production

The effects of drought range from morphological to molecular levels and are evident at all phonological stages of plant growth at whatever stage the water deficit takes place. Water deficit occurs when water potentials in the rhizosphere are sufficiently negative to reduce water availability to sub-optimal levels for plant growth and development. On aglobalbasis, it is a major cause limiting productivity of agricultural systems and food production[25]. In cereal crops, which provide the major carbohydrate staple for humans, even intermittent water stress atcritical stages may result in considerable yield reduction[26].

2.1.1 Crop growth and water deficit

Growth regulations, mainly aimed at limiting shoot growth and there by the evaporation surface, is an integral part of the drought response of many plants[27]. It has become clear that a very fast and actively regulated response that is not merely a consequence of altered hydraulics, as it cannot be abolished when xylem water potential is maintained, and occurs in maize and rice even when the leaf water potential is not affected [28],[29].

The first and fore most effect of drought is impaired germination and poor stand establishment [30]. Drought stress severely reduces germination and seedling stand. In rice, drought stress during the vegetative stage greatly reduced the plant growth and development[32]. Growth is accomplished through cell division, cell enlargement, differentiation, and involves genetic, physiological, ecological, and morphological events and the complex interactions. The quality and quantity of plant growth depend on these events, which are affected by water deficit. Cell growth is one of the most drought-sensitive physiological processes due to the reduction turgor pressure[33].

Under severe water deficiency, cell elongation of higher plants inhibited by interruption of water flow from the xylem to the surrounding elongating cells[34]. Inhibition of cell expansion under drought stress involves both the reduction in turgor and the loss of cell wall extensibility. Loss of cell wall extensibility involves changes in polysaccharide content and structure in the cell wall. In the resurrection plant, *Myrothamnus Flabellifolius*[35], constitutive presence of high concentration of arabinose in cell walls provide the necessary structural properties to be able to undergo repeated periods of desiccation and rehydration. Cell division can occur only after cells reach acertainsize. The integrated and final effect of both cell enlargement and division on leaf growth under stress is the important issue in terms of the whole plant in the field. It has been argued on the basis of experimental workwithmaize[36], that a single leaf growth under drought stress can be predicted and its genetic background might be resolved.

Basic growth process of plant issues might be under a universal genetic control, whether under non-stress or stress conditions.[37,38], Suppose that environmental stresses infarm appear mainly in the form of such factors as water, nutrition and heat deficiency.[39], Conducted that plant height and number of grains head decreased significantly by lowering the nitrogen level or increasing droughtstress.[40], [41], reported that plant height and plant dry matter decreased with increasing water stress under controlled conditions.[42], Showed that with drought stress grain yield decreased about 83 percent because of decreasing in weight of 1000grains and number of grains per head For water stress, severity, duration, and timing of stress, as well as responses of plants after stress removal, and interaction between stress and other factors are extremely important[43]. For instance, water stress applied at pre-anthesis reduced time to anthesis, while at post anthesis it shortened the grain-filling period intriticalegeno types[44]. Inbarley (*Hordeumvulgare*), drought stress affects grain yield by reducing the number of tillers, spikes, grains per plant and individual grain weight. Post-anthesis drought stress was detrimental to grain yield regardless of the stress severity[45].

2.1.2 Physiological bases of yield under drought

A plant responds to a lack of water by halting growth and reducing photosynthesis and other plant processes in order to reduce water use. As water loss progresses, leaves of some species may appear to change color usually to blue-green. Foliage begins to wiltand, if the plant is not irrigated, leaves will fall off and the plant will eventually die. The physiologically relevant integrators of drought effects are the water content and the water potential of plant tissues[46]. Once a drop in water potential develops, responses of a wide range of physiological processes are induced. Some of these responses are directly triggered by the changing water status of the tissues while others are brought about by plant hormones that are signaling changes in water status[47].

As a consequence, it can be expected that there is no single response pattern that is highly correlated with yield under all drought environments. The different crop developmental stages show different sensitivity to drought stress. In wheat most of the floral primordia that reach the fertile florets tage become grains after anthesis. The number of fertile florets of grains per m^2, the most relevant component in ensuring high yield in drought conditions[48], is determined during stemelongation, a few weeks before anthesis.

An extended duration of the stemelongation phase without a change in the timing of anthesis has been proposed as a physiological determinant of an increase in the number of grains per m2 without altering the amount of water used by the crop[49]. In maize a close synchrony between pollen shedatanthesis, silk emergence is required for high kernel set, and a negative relationship exists between final kernel number and the extent of anthesis-silking interval (ASI).Drought stress at flowering causes a delay in silk emergence relative to anthesis[50]. Meiosis, anthesis, and male and female fertility are all extremely susceptible to drought stress and their failure directly affects the kernel number, thus leading to a significant yield penalty. In maizeo vary abortion is greatest when drought is experienced a few days before pollination[51]. Water deficit around pollination increases the frequency of kernel abortion in maize due to a lack of photosynthate and to the disruption of carbohydrate metabolism in ovaries[52].

2.1.3 Drought Stress and Yield Loss

Acute shortage of irrigation water is adversely affecting the crop production in general and vegetable production in particular. Water stress during vegetative or yearly reproductive growth usually reduces yield by reducing the number of seeds soybean[53] and canola[54], while waters tress during seed filling reduces seed size and yield can be reduced by short period of stress during flowering and podset[55]. *Crop Biomass* production is linearly related to crop transpiration, or water use. The equation first proposedby[56], still stands:B=mT/E0,WhereB=total crop biomass, m=crop constant T= crop transpiration and E0= free water(potential) evaporation. The primary consideration for enabling total plant production under drought stress is sustained transpiration. All other considerations as much as they may be important are secondary when production is concerned.

The development of a relationship between economic yield (e.g., grain, fruit, fiber, ortuber) and water use is far more complex where as economic yield is not equated with total biomass. Most research on yield formation has been done in the cereals. Hence, yield of wheat, barley, sorghum, millet, or rice is the multiplication of the number of inflorescence per unit area of land by the number of grains per in florescence, by single grain weight. Even the analysis of panicle weight componential lowed better understanding of yield formation and heterosis in sorghum[57]. Drought stress can reduce yield by affecting the sink or the source. Source capacity is reduced under drought stress as a result of stress effects on leaf area, gas exchange and carbon storage available for grain filling as well as from an increase in leaf senescence and the increase in rate of certain developmental processes. The reduction in sink capacity under drought stress is caused by arrested organ differentiation as well as by the dysfunction of the differentiated reproductive organs. Thus, for example, drought stress reduces the number of tillers either by stopping their sequence of differentiation or by death of growing or grown tillers. The number of flowers (or florets) in the in florescence will be reduced by arrested differentiation or by abortion and degeneration of developed flowers under stress. The reduction in the number of grains developed from a given number of flowers in the in fluorescence can be affected by induced sterility of female or male organ as well as by stress induced abortion of embryo[58].

The specific sensitivity of reproduction to drought stress is compounded by the fact that plants at flowering are large and pose a heavy demand for water. Reproductive failure is basically irreversible unless non-determinate crop plants are considered.[59], indicated that plant height, plant dry matter, stem diameter, headsize, seed number per head, weight of 1000 grains and grain weight per head under dry andsemi-dried conditions declined.[60], showed that with increasing drought stress leaf area index, grain yield and its component decreased.

Drought-induced yield reduction has been reported in many crop species, which depends upon these verity and duration of the stress period. Inmaize, water stress reduced yield by delaying silking, thus increasing the anthesis-to-silk inginterval. This trait was highly correlated with grain yield, specifically year and kernel number per plant[61]. In pearlmillet (*Pennisetumglaucum*), co- mapping of the harvest index and panicle harvest index with grain yield revealed that greater drought tolerance was achieved by greater partitioning of dry matter from Stover to grains [62].

Grain filling in cereals is a process of starchbio synthesis from simple carbo hydrates. It is believed that four enzymes play key roles in this process: Sucrose synthase, adenosine diphosphate-glucose-pyrophosphorylase, starchsynthase and starchbranchingenzyme[63]. Decline in the rate of grain growth resulted from reduced Sucrose synthase activity, while cessation of growth resulted from in activation of adenosine diphosphate-glucose-pyrophosphorylasein the water-stressed wheat[64]. Water deficit during pollination increased the frequency of kernel abortion in maize(*Zeamays*).Under water stress, diminished grain set and kernel growth in wheat and a decreased rate of endosperm cell division was associated with elevated levels of abscisic acid in maize[65].

2.2. Drought Resistance in crop plants

When ageno type yields better than another under a severedoes (below the 'crossover') strain of drought, it is relatively more drought resistant. The strain of drought is developed when crop demand for water is not met by the supply, and plant water status is reduced. Plant scan resist drought by either dehydration avoidance or by dehydration tolerance.

Drought resistance in terms of the physiology involved interacts with the magnitude and the timing of the stress. Timing here refers to the stage of plant development when stress occurs. For example, drought resistance in seedlings grown in a pot has nothing to do with drought resistance during grain filling in the field[66]. It is important to distinguish between what is meant by drought resistance and by drought- associated *traits*. The only criterion to be considered in terms of defining drought resistance should be economic yield (e.g.grain yield in wheat). Thus, a drought resistant variety is one that gives a significantly higher yield than average under specified conditions where yield is limited by water availability.

2.3 Managing drought stress

Drought stress effects can be managed by production of the most appropriate plant genotypes together with adjustment of agronomic practices (sowingtime, plant density and soil management). This Is Done to Ensure That Sensitive Crop Stages occur at the time when likelihood of drought is minimal. Various strategies of paramount importance to accomplish this objective may entail production of appropriate plant varieties and improvement of the existing high- yielding varieties. Efforts have been made to produce drought-tolerant genotypes using the knowledge of responses of plants to drought stress and mechanisms involved as elaborated above. The two most important strategies may include :(a) selecting the desired materialsasin traditional breeding using molecular and bio technological means, including production of genetically modified ortransgenic plants and (b)inducing drought tolerance in otherwise susceptible plants by priming and hormonal application[67].

2.3.1 Selection and breeding strategies

Screening under natural drought stress conditions in the target environments is difficult because of their regular and erratic drought response. However, screening under controlled stress environments and rain out shelters is more manageable. Selection response in the target population of environments under natural stress can be considered a correlated response to selection in the managed stress environment[68].

On the other hand, classical breeding is a good approach for developing drought tolerance, which relies upon multi-location testing of progeniesin environments representing a random selection of the variation in droughts tress in the target environment[69]. A modification to this strategy involves selection for putative drought-adaptive secondary traits[70], either alone or as part of selection index. Selection for low-transpiration types, at unchanged water-use efficiency, would result in lower yields under optimum conditions. Considerable efforts have been targeted at the genetic analysis of secondary traits such as root system architecture, leaf water potential, panicle water potential, osmotic adjustment and relative watercontent[71]. A suitable secondary traitis: (1) genetically associated with grain yield under drought; (2)highly heritable;(3)stable and feasible to measure and(4)not associated with yield loss under ideal growing conditions[72]. However, such traits rarely have high broad-sense heritability like yield under drought stress and are often not highly correlated with it[73].

2.3.2. Marker assisted selection (MAS) to improve drought tolerance

Considering the importance of cereal crops as a predominant source of food around the world, Identification of traits and genotypes associated with drought tolerance is absolutely necessary. Concerted efforts are required to fully understand the physiological and genetic basis of drought tolerance. Focus should be on screening resistant germplasm and discovering potential candidate genes[74].Since drought tolerance characters are quantitative in nature, the complete genetic dissection of these complex traits into component genetic factors is a preliminary task. Therefore, molecular genetic markers offer a great opportunity of locating the QTLs controlling these traits [75].

These molecular markers are very powerful as these remain unaffected by the external environment. Once it is ensured that these markers are tightly linked and tagged with a QTL concerned, selection at early segregating generation canbepursued[76].Thus MAS saves time and valuable resources by eliminating undesirable phenotypic evaluation. Although molecular markers have been successfully associated with QTLs, yet this association has shown limited practicality incereal breeding[77]. One of the prerequisites of MAS is the close linkage of DNA marker with the target locus. However, this link age can be broken by the genetic recombination. Furthermore, the effects of individual QTLs on the phenol type are relatively small. This implies the need to manipulate several (perhaps from three to five)QTLs in the breeding program for significant impact[78].

2.3.3. Transgenic

The identification of candidate genesis critical for our understanding of molecular and physiological mechanisms of drought tolerance, as it will enable us to use transgenic approaches in breeding for a biotic stress tolerance[79]. A transgenic approach is one that involves some structural modifications in traits through gene transfers from one species to the other[80]. As the regulatory networks under lying the abiotic stress responses are being fully understood, more and more candidate genes will be identified to be used in development to transgenic plants [81].

Table 1 List of transgenic lines produced in cereal crops for drought tolerance

Transgene	Crop	Trait improved
HVA1	rice	Transgenic plants showed improved tolerance to drought conditions[82].

HVA1	wheat	Transgenic plants showed improved tolerance To drought conditions[83.]
CBF3/DREB1A	rice	Drought and salinity tolerance[84.]
ZmNF-YB2(anorthologous	maize	Transcription factor from the nuclear factor *Y (NF-Y)*family)maize transgenic maize lines showed improved tolerance to drought[85.]
mtlD(osmoprotectant)	wheat	Improved fresh and dry weights, plant height, and flag leaf length in transgenic plants[86.]
Rice *OsSDIR1*gene		Over expression of *OsSDIR1*gene significantly enhanced drought and salt tolerance[87.]
Tomato Ethylene Response Factor (ERF)protein *JERF3*	rice	Over expression of *JERF3* significantly enhanced drought tolerance of transgenic rice[88.]
*SNAC1*transgenic	rice	Plants showed improve tolerance to droughtconditions[89.]
*OsNAC10*transgenic	rice	Plants showed improved grain yield and tolerance to drought[90.]
Tomato Ethylene response factor(ERF)	rice	Protein *TSRF1TSRF1*improvedthe osmotic and drought tolerance of rice seed lings without growth retardation[91.]
ZmNF-YB2	maize	Transgenic Maize Plants Showed 50% increased yield under drought conditions[92.]
ZmNF-YB2(an orthologous maize transcription factor from the nuclear factor *Y(NF-Y)*family)	maize	Transgenic Maize Lines Showed Improved Tolerance to drought[93.]

2.3.4 Molecular and function algenomics approaches

For more than two decades, molecular and biochemical studies have identified many of the abscisic acid -and stress responsive genes and a few of the transcription factors responsible for the induction in crop plants[94]. The products of certain stress responsive genes could function in alleviating stress damage through still elusive mechanisms[95]. Many laboratory and field studies have shown that transgenic expression of some of the stress-regulated genes results in increased tolerance to drought and other stresses. These transgenic approaches are currently the main stream method to bioengineer drought tolerance in crop plants[96]. Arising from breeding or bioengineering, the next generation of drought-tolerant crop plants requires better understanding of the molecular and genetic basis of drought resistance[97]. In this regard, rice, asubmerged plant, offers an excellent model for the precise understanding of drought tolerance phenomena. An increasing number of studies witnesses that rice display early morphological changes upon exposure to drought at various growth stages[98]. Since drought tolerance is agenetically controlled phenomenon, many quantitative trait loci for membrane stability and other functionally related phenomena genes have been characterized using bio informaticstools[99].

2.3.5. Induction of drought resistance

Drought resistance can be induced by adopting various strategies. Of these, exogenous use of various growth regulating and other chemicals has proven worthwhile in producing drought resistance at various growth stages in a number of plants.

2.3.5.1 Seed priming

One of the short-term and most pragmatic approaches to overcome the drought stress effects is seed priming. Seed priming is a technique by which seeds are partially hydrated to a point where germination-related metabolic processes begin but radical emergence does no to ccur[100]. Primed seeds usually exhibit increased germination rate, greater germination uniformity, and sometimes-greater total germination percentage[101,102]. This approach has been applied to overcome the drought stress effects in arrange of crop species[103], while testing the effectiveness so different osmoticato improve the performance of direct-seeded rice, noted that osmo priming with 4% KCl solution and saturated $CaHPO_4$ solution was success fulin improving these edling emergence, crop stand establishment and yield under stress. In drought- prone areas primed rice seeds germinate well and seedlings emerged faster and more uniformly, leading to increased yield [104]. Seed priming improved performance of wheat seeds under drought stress in terms of germination and water-use efficiency of drought-stressed plants by 44% compared with unprimed seeds[105]. The beneficial effects of priming included faster emergence of crop seedlings, early flowering and higher grain yield even under drought stress[106]. In sunflower, osmo priming with KNO_3 and hydro priming improved the germination and stand establishment under stress conditions [107].

2.3.5.2. Use of plant growth regulators

Foliar Application of plant growth regulators, both natural and synthetic, has proven worthwhile for improving growth against a variety of a biotic stresses. Drought stress alone inhibited increases in length and fresh weight of the hypocotyls, while applied levels of gibberellic acid reversed this effect. In this case, gibberellic partially increased the water status of the seedlings and partially sustained protein synthesis[108]. Exogenous application of gibberellic acid increased the net photosynthetic rate, stomatal conductance and transpiration rate in cotton [109], and stimulated pollen and seed cone production in Sitkaspruce(*Piceasitchensis*) under drought stress[110]. Among other hormones, exogenous application of 1-aminocyclopropane-1-carboxylicacidalsoimproves drought tolerance by delaying senescence[111].In another study, exogenously applied uniconazole, brassinolide and abscisic acid increased soybean yields both under well watered and water deficit conditions. Under water stress conditions, plant growth regulator significantly increased water potential, and improved chlorophyll content[112]. Salicylic Acid can also effectively improve plant growth under drought conditions[113].

In a recent study, exogenous application of salicylic acid improved the drought tolerance of winter wheat, which was correlated with an increased catalase activity [114]. Both salicylic acid and acetylsalicylic acid (a derivative of salicylicacid), applied at various concentrations through seed so a king or foliar spray protected muskmelon (*Cucumismelo*) seedlings, subjected to drought stress. However, the best protection was obtained from seedlings pretreated with lower concentrations of salicylicacid [115].

2.3.5.3 Use of Osmoprotectants

Osmoprotectants are involved in signaling and regulating plant responses to multiple stresses, including reduced growth that may be part of the plant's adaptation against stress. In plants, the common osmo protect antsareproline, trehalose, fructan, mannitol, glycinebetaine and others[116]. They play adaptive roles in mediating osmotic adjustment and protecting subcellular structures in stressed plants.

However, not all plants accumulate these compounds in sufficient amount to avert adverse effects of drought stress[117], [118], outlined three approaches to increase the concentrations of these compounds in plants grown under stress conditions to increase their stress tolerance:

I. Use of traditional protocols of plant genetics and breeding to develop cultivars with natural abilities to produce high levels of these compounds under stress conditions,

II. Engineering genetically modified plants cap able of producing sufficient amounts of these compounds in response to environmental stresses and

III As a short-cutmethod, exogenous use of these osmolytes on plants to enhance their stress tolerance ability

2.3.5.4. Silicon

Silicon is the second most abundant element in soils and a mineral subst rate for most of the world's plant life. Ample evidence is available indicating that when siliconis readily available able to plants, it plays a significant role in their growth, mineral nutrition, mechanical strength and resistance to several stresses[119]. It has not been considered an essential element for higher plants yet, partly because its role in plant biologyis less well understood[120]. Nevertheless, numerous studies demonstrate that silicon is an important element, and plays an important role in tolerance of plants to environmental stresses [121].With respect to drought stress, relevant work is limited onsilicon. Sorghum (*Sorghumbicolor*) plants grown in pots in the presence of silicon had higher relative water content and dry materials by improving shoot water up take[122].Wheat plants applied with silicon could maintain better water status and higher content of dry materials compared with non-silicon treat mentunder drought[123]. Exogenously applied silicon lowered the shoot to root ratio, indicating the facilitation of root growth and maintenance of a higher photosynthetic rate and stomatal conductance compared with plants grown without silicon application under droughtstress[124].In another study[125], opined that the silicon-triggered improvement in drought tolerance of wheat plants was associated with an increase in antioxidant defense, there by alleviating oxidative stress on functional molecules of cells.

3. CONCLUSION

Drought stress has a great impact on the reproductive development of crops and consequently on final seed yield. The degree of drought stress is clearly determining factor for pollination, seed set, yield and quality in all species, However, where the final yield is concerned, all breeding manipulation strategies/approaches used in crop improvement under drought stress have to focus finally on flowering and/or grain development. Classical breeding is a good approach for developing drought tolerance, which relies upon multi-location testing of progenies in environments representing random selection of the variation in drought stress in the target environment. Identification of drought related quantitative trait loci (QTLs) coupled with marker assisted selection has shown some positive results. Transgenic technologies promise to make progress in breeding for drought tolerance through a more fundamental understanding of underlying mechanisms of drought tolerance and identifying potential candidate genes. These new approaches provide opportunities to direct the continued breeding of genotypes giving stable yields under drought.

SIGNIFICANCE STATEMENT

This review focuses on production of appropriate plant varieties and improvement of the existing high-yielding varieties through production of drought-tolerant geno types using the knowledge of responses of plants to drought stress and mechanisms. This review therefore aims at uncover critical area of drought stress on crop plant and managing drought stress by production of appropriate plant genotypes together with agronomic practices that many researchers were not able to explore. Identification of traits and genotypes associated with drought tolerance is absolutely necessary. Concerted efforts are required to fully understand the physiological and genetic basis of drought tolerance that will provide a comprehensive and integrated selection basis in drought stress tolerance breeding programs.

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