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A REVIEW ON VARIOUS FACTORS WHICH AFFECTING SUSTAINABLE MAIZE (*Zea mays* L.) PRODUCTION UNDER DROUGHT STRESS

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ABSTRACT

Maize is an essential dietary component in human food and in animal feed formulation throughout the world. With the rising trend of global climate change, grain yield and quality losses of maize are expected to increase, because of various biotic and abiotic stress in all over the world. Among these, drought is most considerable one; it remarkably influences the growth and yield traits of maize. Hence, improve of drought tolerant in maize genotypes have potential to stabilize, and even though increases the grain yield of maize. Therefore, developing cultivars tolerant to drought stress is a challenge for breeders. There are two ways to mitigate drought stress in maize production, either by developing and practicing improved drought management practices, or by developing and using drought-tolerant cultivars. Even though researchers in all over the world are trying to develop maize genotypes those are

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tolerant to drought stress; however, a effective breeding program is required to develop and detect the drought-tolerant traits. Therefore, the present review aim to address the adverse effect of drought stress on growth, yield traits, physiological and biochemical process of maize. It also attempts to identify the survival mechanism under drought stress for genetic improvement of maize. The present revi533ew also try to find out the effect of plant growth regulators, enzymatic antioxidants especially osmoprotectants and fertilizer (organic and inorganic) on the morphological, physiological as well as chemical process of plants for better adaptation under harsh environments.

1 Introduction

Maize is an important cereal crop with a wider range of uses than other cereals (Olaniyan, 2015). It is a necessary crop which used as food, fodder, fuel, as well as in the manufacture of industrial products. Furthermore, oil of maize is appropriate for human consumption due to the presence of unsaturated fatty acids. Because of diverse uses including human consumption, livestock feed formulation, pharmaceutical, textile industries and biofuel production its demand increasing day by day (White & Johnson, 2003; Ali et al., 2010). However, the production capacity of maize is not adequate to meet the utilization demand. Therefore, to meet the increasing demands greater efforts should be taken under different environmental conditions (Karasu et al., 2015).

Drought stress is one of the most limiting growth factors and a major constraint to agricultural production in many developing countries of the arid and semi-arid regions of the world (Turhan & Baser, 2004; Golbashy et al., 2010; Hossain et al., 2013; Hassan et al., 2016). Drought conditions affecting crop growth by changing various physiological and metabolic processes (Lunde et al., 2007; Islam et al., 2011). Grain yield is the most commonly studied parameters; therefore most of the plant breeder basically focused on the increasing crop yield (Ignjatovic-Micic et al., 2014). While, they give less attention to the grain quality parameters such as grain protein, oil and starch content. According to Boyer & Hannah (2001) and Rehman et al. (2011) grain protein, oil and starch content are the quality parameters which usually show stability under adverse environmental conditions and are less affected by various environmental changes. In contrast to this various studies revealed that water stress equally affected the quantitative and qualitative traits (Rashwan et al.,2016; Barutçular et al. 2016b; Barutçular et al. 2016c ; EL Sabagh et al.,2017b; Abdelaal et al., 2017a). According to Zhao et al. (2009) maize protein components are sensitive to drought stress when it occurs during grain filling stage.

Although drought affects plant from seedling to maturity but maximum yield reduction occurred when plant face drought conditions at the reproductive stage and it is greater than the vegetative and grain filling stages (Khalili et al., 2010). Drought stress at the vegetative, pollination and grain filling stages can cause 15, 40, and 60% yield losses in maize respectively (Khodarahmpour & Hamidi 2012). Further, Shaw (1977) reported that drought stress caused higher yield reduction in maize than those caused by other potential climatic stresses. When it occurred during silking-tasseling phase (flowering and pollination) it reduces grain yield by as much as 7% per day of stress. Prolonged period of drought shortened the grain filling period and finally reduced grain yield of maize (Gooding et al., 2003).

Developing cultivars tolerant to drought stress is a major challen for breeders (Timsina & Connor, 2001). There are two ways to mitigate stresses, either by developing and practicing improved stress management practices, or by developing and using drought-tolerant cultivars (Farooq et al., 2011). Therefore, it is very essential to improve existing as well as new breeding methods by using multi-disciplinary approaches for developing good genotypes that are tolerant to abiotic stresses specially drought for Arid and Semi-Arid environments (Cairns et al., 2012a).

Stress tolerance indices (STI) are useful tools for determining high yield and stress tolerance potential of crop genotypes. STI has been commonly accepted for identifying high yielding crop genotypes under both stress and non-stress conditions (Lan, 1988; Mitra, 2001; Jafari et al., 2009; Naghavi et al., 2013; Barutçular et al., 2016a). For screening drought-tolerant genotypes, the most commonly used stress tolerance indices are stress susceptibility index (SSI) (Fischer & Maurer, 1978), stress tolerance index (STI), tolerance index (TOL) (Rosielle & Hamblin, 1981), yield index (YI) (Gavuzzi et al., 1997), yield stability index (YSI) (Bouslama & Schapaugh, 1984), mean productivity (MP) and geometric mean productivity (GMP) (Fernandez, 1992).

The present review aim to know the adverse effect of drought stress on growth, yield, qualitative traits, physiological and biochemical process of maize and also attempt to identify the survival mechanism under drought stress. The review also tries to identify the important drought tolerance indices.

2 Influence of drought stress on maize seedling establishment

Drought is a major abiotic stress limiting crop growth rate because of its negative consequences on the various cellular activities. Wenkert et al. (1978) reported reduction in cellular elongation and wall synthesis in germinating seed if they exposed to water stress. Further, detrimental impact of drought stress on the initial phase of growth and seedling establishment of maize plants cannot be ignored (Shao et al., 2008). Hence, adequate moisture availability is important for the development of maize from seed germination and seedling establishment to physiological maturity. Drought stress reduced the rate of seed germination in maize crops, however, maize varieties differed significantly in response to drought stress environment (Anjorin et al., 2017). The drought tolerant maize varieties germinated earlier than the non-drought tolerant maize varieties under critical level of soil moisture when maize varieties were subjected to varying water regimes. Naturally, plant employs several adaptive measures to cope with harsh weather conditions, such adaptive measures bring changes or adjustment in the physiological and biochemical processes of plant. Some common adaptive major which used by various plant species are stomata aperture closes, reduction in leaves formation, reduction in total leaf area and reduction in plant height (Boyer & Kramer, 1995; Anjum et al., 2011). Similarly, Saliendra & Meinzer (1991) also reported that reduction in water potential induces stomatal closures resulting in a decline in the rate of photosynthesis, leaf growth and ultimately yields.

Two types of organic solutes i.e., nitrogen-containing compounds and the hydroxyl compounds produced by plants under stress condition for metabolic adjustment (Yancey et al., 1982). In case of nitrogen-containing compounds proline, other amino acids, quaternary ammonium compounds and polyamines are most common one while in case of hydroxyl compounds sucrose, polyhydric alcohols and oligosaccharides are widely synthesized by plants (McCue & Hanson, 1990). Similarly, Farooq et al. (2009) stated that osmotic adjustment is a mechanism that maintains plant water relations under osmotic stresses through accumulation of a wide range of osmotically active molecules/ions including soluble sugars, sugar alcohols, proline, glycine betaine, organic acids, calcium, potassium, chloride ions, etc. The production of these metabolite helps to protect plant cells against the deleterious activities of reactive oxygen species (ROS) produced during water stress. In young maize water stress metabolites such as soluble sugar and proline increased with increased water stress while starch content and relative water content reduced with increased drought (Izanloo et al.,2008; Nayer & Reza, 2008; Anjorin et al.,2016). Selection of drought tolerant plant using biochemical component have been described as a fast indirect and reliable method and it is equal effective at seedling stage also (Schiop et al., 2015). However, drought tolerant maize varieties that produced highest antioxidant metabolites are not usually the highest yielding varieties (Anjorin et al., 2016; Anjorin et al., 2017). Similarly, Nazarli & Faraji (2011) suggested that several factors should be put into consideration when selecting for drought tolerance in maize. They also noticed that drought tolerance is a complex process that depends on action and interaction of different physiological, biochemical parameter as well as different morphological traits, such as leaf rolling, efficient rooting system, etc.

3 Physiological responses of maize under drought

The performance of crop under drought condition is a complex phenomenon, when drought occurs during the reproductive growth stage, plant reduce the demand for carbon by decreasing the size of sink which eventually diminished the grain yield of crop (Reynold et al., 2006). Acclimation of different organic solutes, changes in plant growth and physic-biochemical processes, such as changes in plant structure, growth rate, osmotic potential of plant tissue and antioxidant defenses in plants lead to adapt/survive plant under drought condition (Duan et al., 2007; Chen et al., 2010a; Köksal, 2011). While, in most cases grain yield and drought adaptation are complex phenomenon (Bruce et al., 2002). Also, in drought breeding programmes, identification of phenotypic, ideotype traits and donors are important (Cairns et al., 2012b). The changes in leaf morphology induced by drought caused higher reflectance in the visible spectra between stressed and unstressed maize leaves (Genc et al., 2013).

Physiological trait such as stomatal conductance is an important feature which influenced yield significantly under drought stress and it is an important indirect drought tolerant crop selection criterion (Dodd, 2003; Koc et al., 2008). Stomatal conductance is a key trait of photosynthetic leaf that significantly influenced by water stress (Jiang et al., 2006). But, soil drying or drought condition leads to a reduction in stomatal aperture and stomatal conductance (Songsri et al., 2013; EL Sabagh et al., 2017a; Barutçular et al., 2017), therefore, plants under drought condition exhibited reduced rate of photosynthesis. High stomatal conductance could be a major determinant for high grain yield in maize under stress condition at grain filling stage (Munjal & Rana 2003). Drought could also lead to increased stomatal density and reduced stomatal size, for adaptation of plants under drought stress (Martinez et al. 2007). In maize, some drought tolerant genotypes reduce leaf stomatal conductance more on the onset of drought (Ray & Sinclair, 1997). A significant genotyic variation in relation with stomatal conductance of maize genotypes was recorded at 7 and 21 days after anthesis under full irrigation and deficit irrigation regimes (EL Sabagh et al., 2017a; Figure 1 & 2). Similarly, Bahar et al. (2009) found a significant correlation effect between stomatal conductance and yield. Similarly Kolb &

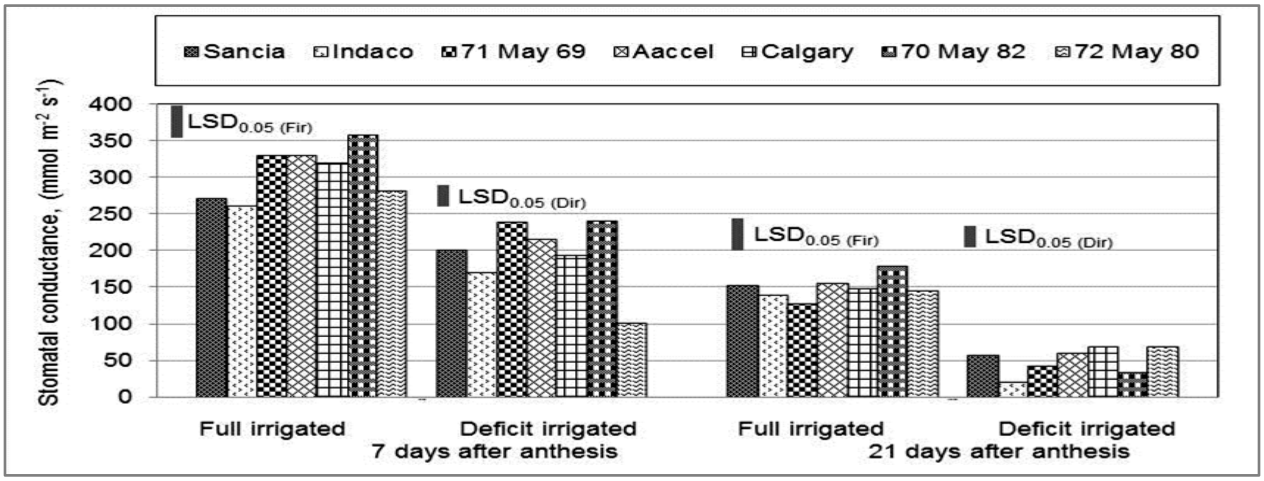

Figure 1 Stomatal conductance in maize genotypes at 7 and 21 days after anthesis under full irrigation and deficit irrigation regimes (EL Sabagh et al., 2017a).

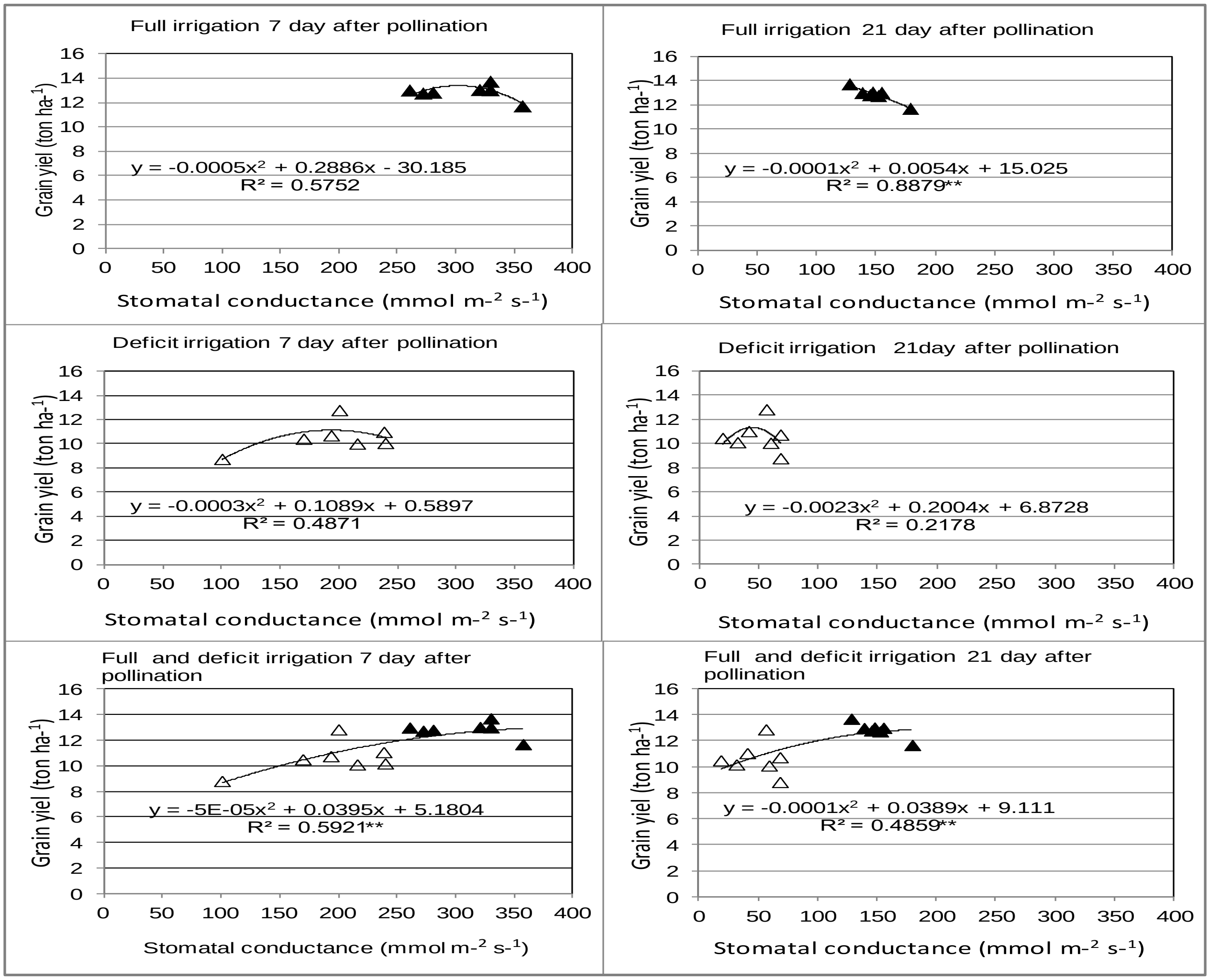

Figure 2 Relationships between grain yield and stomatal conductance of maize at 7 and 21 days after anthesis under full irrigation and deficit irrigation regimes (EL Sabagh et al., 2017a).

Robberecht (1996) found a positive relationship between stomatal conductance and transpiration. The remarkable genotypic variation in the stomatal conductance was observed by Bahar et al. (2009). However, a non-significant correlation between stomatal conductance and grain yield was also reported by Anjum et al. (2008).

Generally, reduced canopy senescence and higher leaf chlorophyll are correlated with the increased grain yield of hybrids under well-watered conditions (Lee & Tollenaar, 2007; Barutçular et al., 2016c). A significant relationship was recorded between SPAD value and grain yield of wheat after anthesis, while no significant association was observed during middle and late grain-filling stages (Monneveux et al., 2008; Akhter et al., 2016). Further, SPAD values might be used as an indicator of grain yield in wheat (Barutçular et al., 2016d). Leaf area determines the growth rate and crop yield besides its efficiency to produce photosynthates (Ritchie & Burnett, 1971). Further, Athar & Ashraf (2005) found that moisture deficit root zone reduced leaf area, chlorophyll contents and photosynthetic rate of maize. The reduction in relative water contents under drought resulted in wilting, stomatal closure and reduced growth (Lawlor & Cornic, 2002; Unyayar et al., 2004). Similarly Abdelaal et al. (2017b) suggested that abiotic stresses led to changes in the membrane permeability (electrolyte leakage) of plants.

4 Effect of drought on grain yield and yield components of maize

Yield attributes such as, stem length, ear height, number kernels row^{-1}, grain weight, grain yield, biomass yield and harvest index of maize were adversely affected by drought stress (EL Sabagh et al., 2017a). While, Abd el-wahed et al. (2015); EL Sabagh et al. (2017a) and Abdelaal et al. (2017a) found that under well-irrigated condition (without moisture stress) the grain weight and other yield traits' values were significantly increased as compared to drought condition. Similar impacts of water deficit and well-water regimes on yield traits and grain yield of maize had been well reported in several studies (Cakir, 2004; Moser et al., 2006; Rivera-Hernandez et al., 2010). Shoa Hoseini et al. (2007) and Golbashy et al. (2010) reported reduction in number of kernels per row and total number of kernelsper ear under water stress conditions. Similarly, Yazar et al. (1999) observed that under water stress, kernels plant^{-1} were decreased significantly that ultimately lead to decrease the grain yield of maize.

Water stress during the critical period of silking to early grain filling, inhibits photosynthesis rate and consequently lowers the carbohydrate reserves that are insufficient to support optimum reproductive development; causes reduction in the photosynthates mobilization to seeds and there by reduction of grain weight (Eck, 1986).While, Kamara et al. (2003) reported that irrigation disruption at grain filling stage decreasing grain weight, due to decrease in the remobilization of photosynthates into the grains. Other researchers noticed that the reduction in grain yield was primarily associated with reduction in number of kernel and secondarily kernel weight when drought stress was imposed during the vegetative and reproductive growth phases in maize (Pandey et al., 2000; Shoa Hoseini et al., 2007; Golbashy et al., 2010). Likewise, drought stress between initial flowering and grain filling stage reduced total grain yield primarily by reducing vegetative growth, which consequently resulted in reduced number of grain and grain yield (Frederick et al., 2001; Leta et al., 2001; Karimian et al., 2005; EL Sabagh et al., 2017a). While, drought stress at pollination stage affects grain formation of maize because of reduced photosynthesis, leading to assimilate deficiency, increase production of sterile pollen ultimately reduced number of grain per ear (Setter et al., 2001; Araus et al., 2010). Farooq et al. (2009) noticed that the deficiency of water vegetative to reproductive stage of maize leads to severe reduction in yield of crop. Earlier findings also reported that anthesis period is the most sensitive stage to drought in maize growth and development that ultimately reduced that grain yield (Cakir, 2004, Zharfa et al., 2011; EL Sabagh et al., 2015a; Barutçular et al., 2016a). Stone et al. (2001), Bänziger et al. (2002) and Zharfa et al. (2011) also established a strong relationship between biomass accumulations (especially after silking) and grain yield. Furthermore, they also observed that the higher growth rate ability of cultivars reduced when they are exposed to water stress condition.

5 Genotypic and phenotypic variation of maize genotypes under drought stress

The significant variations among different maize genotypes with respect to grain yield and yield traits indicate the existence of genetic variation and possibility of selection for drought tolerance genotypes (EL Sabagh et al., 2017a). Grain yield of maize is a consequence of the interactions of various growth traits and yield components. The kernel number per area was significantly affected by water stress conditions (EL Sabagh et al., 20017a). Reality of high diversity among maize hybrids for drought tolerance had been reported by Golbashy et al. (2010). The adverse effect of drought stress on the physiological traits of maize genotypes by reducing the production of dry matter disrupts the partitioning of carbohydrates to grains and decreasing the harvest index (Mostafavi et al., 2011). Anjum et al. (2011) found a significant reduction of kernels row^{-1}, kernel weight, kernels cob^{-1}, grain yield, biological yield and harvest index of maize, when a maize plant was exposed to drought at the tasseling stage. Pandey et al. (2000) noticed that yield loss in maize genotypes between 22.6 to 26.4% caused by deficit water which ultimately reduced the number of kernels as well as grain weight.

6 Correlation analysis between growth traits and yield attributes

A suitable index must have a significant correlation with grain yield under stress conditions as reported by Golbashy et al. (2010) and Shoa Hoseini et al. (2007). EL Sabagh et al. (2017a) found significant correlation coefficients between grain yield and grain weight, while kernels row^{-1}was negatively correlated with grain yield. They also found significant positive correlation between grain yield and drought resistance index (DRISC) (r=0.784, P<0.037) (in the young leaves) under water stress environment (EL Sabagh et al., 2017a; Figure 3 & 4). Higher value of DRISC indicated highly resistance of maize genotypes under drought stress and can be used as drought tolerant genotypes for future breeding program. Stress tolerance index (STI) is also an important index that could be used to identify stress-tolerant high

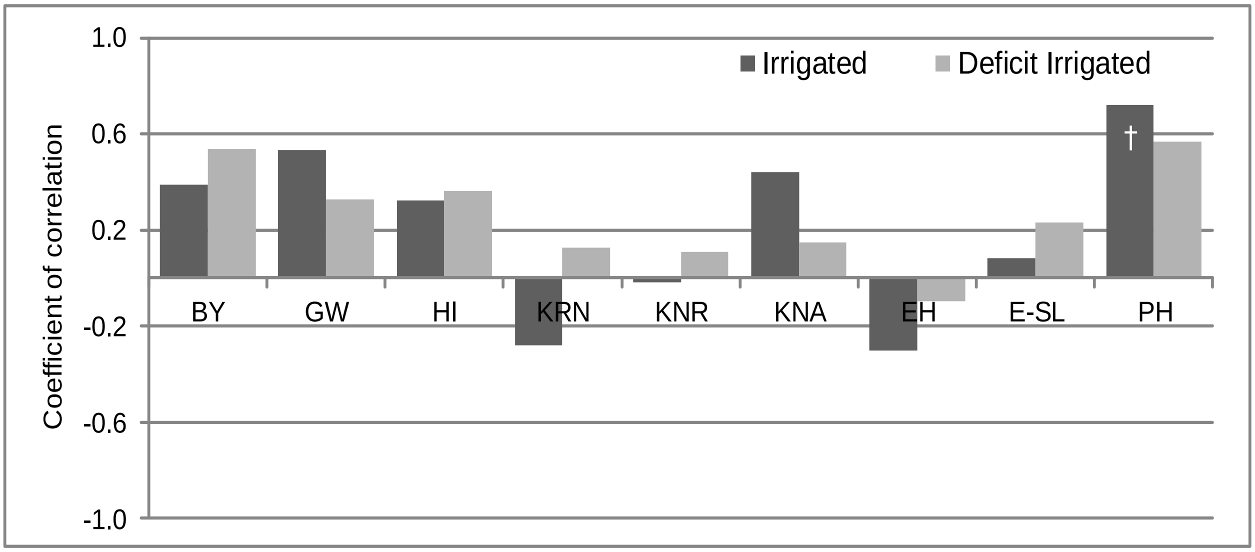

Figure 3 Pearson correlation coefficient between grain yield and agronomic traits of maize hybrids under irrigation regimes (Two years average) (Barutçular et al.,2016a); Column marked by † are significant P=0.057 level; PH - plant height; E-SL - ear-up stem length; EH - ear height; KRN - kernel row number per-ear; KNR - kernel number per row; KNA - kernel number per area; GW - grain weight; HI - harvest index; GY - grain yield; BY - biomass yield

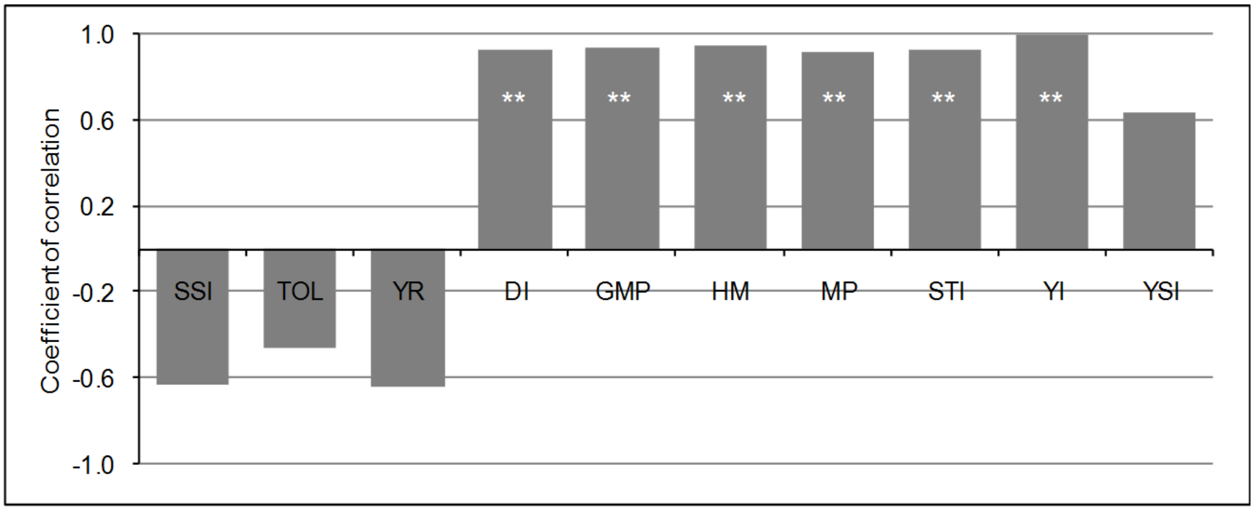

Figure 4 Pearson correlation coefficients between grain yield and drought indices (Two years average) (Barutçular et al.,2016a). Column marked by ** are significant P<0.01 level; SSI - stres susceptibility index; TOL - tolerance index; YR - yield reduction ratio; DI - drought resistance index; GMP - geometric mean productivity; HM - harmonic mean; MP - mean productivity; STI - stress tolerance index; YI - yield index; YSI - yield stability index.

yielding genotypes (Sanjari, 2000; Kharrazi & Rad, 2011). The correlation between stomatal conductance and grain yield were positive (but non-significant) at early milky stage (r = 0.165) but non-significant at late milky stage (r = -0.234) under normal watering, while no positive correlation between stomatal conductance and grain yield was observed at early maturity stage under water stress condition (Bahar et al., 2009). Maize grain yield was negatively correlated with root and leaf growth rates under water stress condition. However, Zharfa et al. (2011) reported a strong correlations between root growth and maize grain yield under normal condition.

7 Selection of drought tolerant genotypes based on tolerance indices

Drought tolerance is often a tedious process because of complex genotypes and environment interactions (Fernandez, 1992; Naghavi et al., 2013).Several drought tolerance indices could be used for screening drought-tolerant genotypes, based on yield loss as compared with normal conditions (Mitra, 2001; Jafari et al., 2009; Naghavi et al., 2013). Barutçular et al. (2016a) found a high correlation between the grain yield and drought tolerance indices and also noticed that these are most suitable selection indices to identify the best maize genotypes for drought condition (Figure 3 & 4). Drought sensitivity and tolerance indices of the maize genotypes were determined based on the grain yield obtained under stress condition.

The correlation between grain yield and drought tolerance indices can be used for identifying the best genotypes which are suitable to grow under drought condition (Barutçular et al., 2016a).Genotypes with high values of STI, GMP and MP can be selected as drought tolerant genotypes (Hossain et al., 2013; Barutçular et al.,2016a; Figure 3 & 4). Furthermore, Hossain et al. (2013) and EL Sabagh et al. (2017a) noticed that TOL and SSI appeared to be most suitable indices for selection of high yielding genotypes under drought stress. The genotypes with high values of yield stability index (YSI), drought resistance index (DI) and harmonic mean (HM) might be selected as tolerant genotypes to water stress (EL Sabagh et al., 2017a). In view of Abdipour et al. (2008), MP, GMP and STI were suggested as the best indices for separating drought tolerant genotypes. Khalili et al.(2012) and Jafari et al.(2009) observed that GMP, MP, and STI indices were positively correlated with yield under both control (well-irrigated) and drought stress conditions and could be used in maize breeding programs as a reliable selection methods to produce drought tolerant maize hybrids.

8 Approaches for Management drought stress to enhance the productivity of maize

Managing water consumption of the crops is one of the strategies which have been adopted locally and worldwide in current trends of sustainable agriculture. Plants can survive under different stress conditions by mobilizing various defense mechanisms as well as altering their physiological metabolism, and growth pattern (Mittler, 2002). Various previous investigations have revealed several biochemicals, physiological and morphological changes in plants in response to water deficit (Basu et al., 2010; EL Sabagh et al., 2016a). Zhang et al. (2009) reported that during osmotic stress (drought), an increase in external osmolarity occurred that ultimate results in an efflux of water from the interior, leading to a reduction in the turgor pressure in the cell as well reduction in the cytoplasmic volume. Therefore, accumulation of osmolytes is a prerequisite for osmotic adjustment of all organisms under drought stress (Zhang et al., 2009).

Plant growth regulators also played vital roles in coordination of many physiological processes including drought (Anjum et al., 2011; Abo-Youssef et al., 2017; Abdelaal et al., 2017a - Figure 5). Various organic compatible solutes including proline (PRO), glycine betaine (GB), trehalose (Tre), salicylic acid (SA), ascorbic acid (AsA) and several others before or during environmental stress protect plants against stress damage (Monyo et al., 1992; Makhdum & Shababuddin 2006; Mattioli et al., 2009; Ali & Ashraf, 2011; Kaya et al., 2013; Reddy et al., 2013).

Several studies reported that exogenous application of proline (PRO) help to survive plant under different abiotic stresses, including drought (Ali et al., 2007; Ali et al., 2008). Although little attention has been given to the role of PRO in affecting the uptake and accumulation of inorganic nutrients in plants, however, many studies have given a much attention on stress tolerance in plants as a compatible osmolyte for osmotic adjustment during drought stress (Ali et al., 2007; Ali et al., 2008). Further, another important phytochemical glycine betaine (GB) is a quaternary ammonium compound and very effective compatible solute that accumulates in plants' leaves during various types of environmental stresses including drought (Ashraf & Foolad, 2007; Zhang et al., 2009).

Like proline and glycine betaine, Salicylic acid (SA) also naturally occurring plant hormone and have influences on various physiological and biochemical properties of plants. It has been also proposed that salicylic acid (SA) acts as an endogenous signal molecule responsible for inducing environmental stress tolerance in plants (Gunes et al., 2005). It is also involved in biochemical pathways, stress and disease resistance and many other plant responses (Kovacik et al., 2009). According to Elwana & El-Hamahmy (2009), SA enhanced photosynthetic rates, leaf

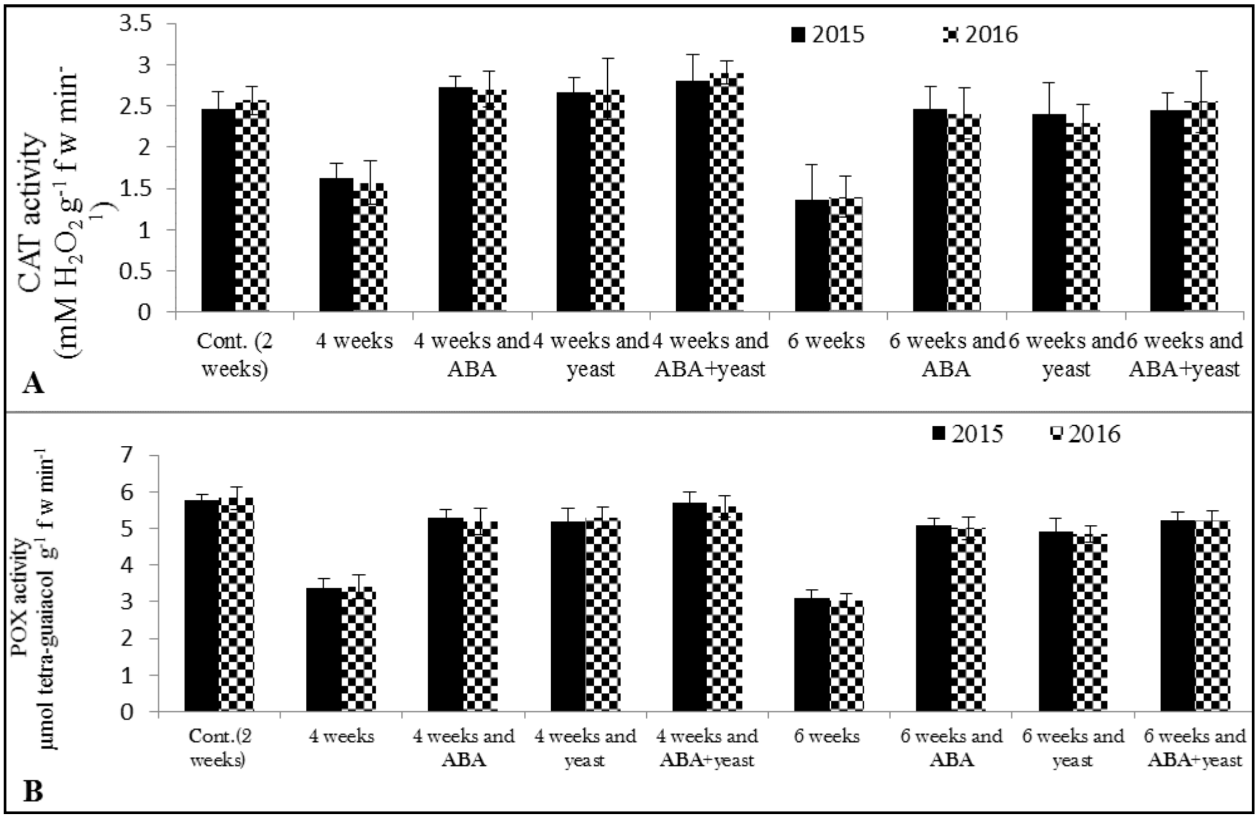

Figure 5 Effect of abscisic acid (ABA), yeast on CAT (A) and POX (B) activates of maize plants under drought conditions during the two seasons 2015 and 2016 (Abdelaal et al., 2017a).

area and plant dry matter production. Salicylic acid also acts as a potential non enzymatic antioxidant in regulating a number of plant physiological processes including photosynthesis (Khan et al., 2003; Arfan et al., 2007; Gharib et al.,2016).

Exogenous application of ascorbic acid (AA) ameliorates adverse effects of drought (Dolatabadian et al., 2010; Khalil et al., 2010). It acts as a plant growth regulator and help in cell division and differentiation (Blokhina et al., 2003). It is also well reported that ascorbic acid maintain water status by regulated stomatal conductance and rate of transpiration (Ashraf, 2009). Ascorbic acid not only acts as an antioxidant but it activates a complex process of defense mechanism (Conklin & Barth, 2004). Ascorbic acid has been also used to counteract the adverse effects of salt stress in many crop plants (Khan et al., 2010). Various other researchers (Dolatabadian et al., 2010, Dolatabadian et al., 2010; Khalil et al., 2010; Yazdanpanah et al. 2011) also reported that under stress conditions, the amount of ascorbic acid in plant increases and this plays a significant role in regulation of mechanisms of photosynthesis and defense against oxidative stress.

Abscisic acid (ABA) could be enhancing plants resistance to environmental stresses (Giraudat et al., 1994). Pre-soaking seed treatment with ABA was positively improve the antioxidant enzymes activity in maize seedlings under water stress conditions (Jiang & Zhang 2002). Application of ABA stimulated the morphological and anatomical modication which could provide the roots to breakthrough compacted soil (Hartung et al.,1994).Abdelaal et al. (2017a) found that grains ear^{-1}, 100 grain weight and grain yield of maize was highly influenced by abscisic acid (ABA) and yeast under drought conditions (Figure 6).The active yeast extract significantly improved growth and agronomical attributes of plants (Hammad, 2008; Rania et al., 2011). Further, agronomical traits positively enhanced in stressed treated plants in maize and improved the growth characters and antioxidant enzymes activity by abscisic acid (ABA) and yeast application (Figure 5 and 6). Application of ABA significantly improved the antioxidant enzymes activity under drought stress in corn crop (Lee & Luan , 2012; Abdelaal et al., 2017a).

The Fertilizer application management, balanced nutrients in plants is a major element to enhance the growth and productivity

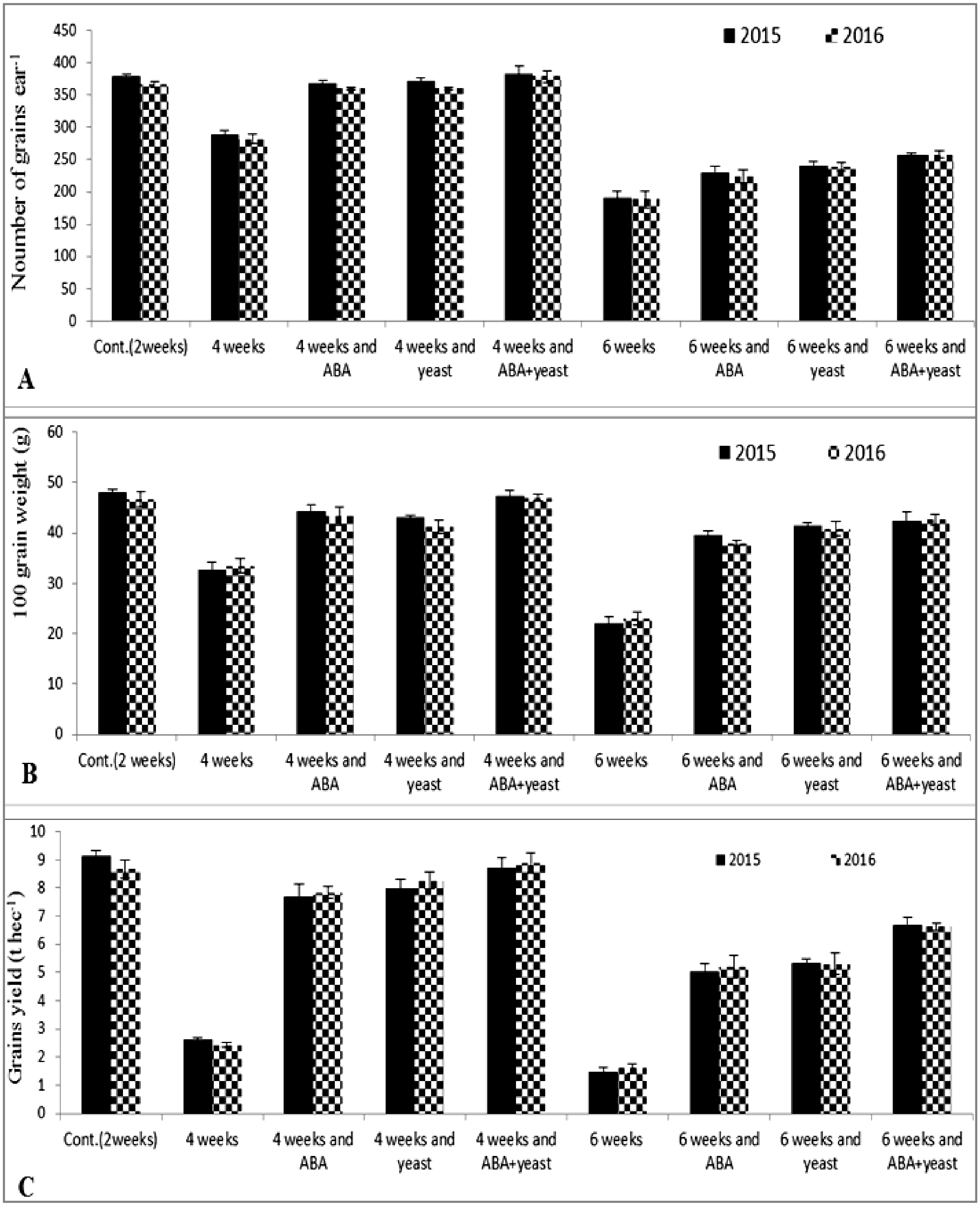

Figure 6 Number of gains ear^{-1}(A), 100 grain weight (B) and grain yield (C) as affected with abscisic acid (ABA) and yeast of maize plants under drought conditions during 2015 and 2016 seasons (Abdelaal et al., 2017a)

of crop under semi arid conditions (Amanullah et al., 2016). Intensive using of mineral fertilizers a main problem to environmental and production cost (EL Sabagh et al.,2015b; EL Sabagh et al., 2016b; EL Sabagh et al., 2016c).The application of organic and inorganic fertilizers improve the activities of soil and nutrient availability (He & Li, 2004; Nasim et al. , 2012). Application of organic fertilizers is very effective for reducing negative effect of stress and increase the yield and quality of crops (Ahmad & Jabeen, 2009; EL Sabagh et al., 2015b). While, Abd El-Wahed et al. (2015) found a positive relationship between amount of irrigation water and grain yield at different FYM treatments under drought stress condition (Figure 7), indicating that FYM in combination with amount of irrigation help to survive plants under deficit water stress condition. Preap et al. (2002) and Gharieb et al. (2016) also reported that organic fertilizers might play an important role in solving environmental pollution problems that caused by agro-industrial wastes. The combined chemical and poultry manure fertilization (50:50) produced maximum yield and growth traits of maize (Nasim et al. (2012). According to Azab (2016) application of half rate of the chemical NPK combined with bio-fertilizers was effective and logic to achieve the maximum productivity under the condition of investigation in maize.

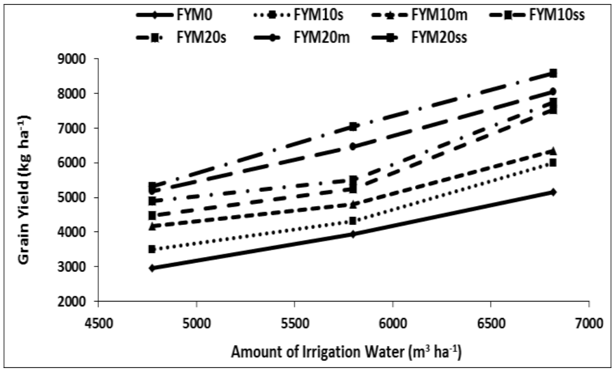

Figure 7 The relationship between amount of irrigation water and grain yield at different farmyardyard manure (FYM) treatments (Abd El-Wahed et al., 2015).

Conclusion

From the present review, it can be concluded that, with the rising trend of global climate change, especially due to drought stress, growth and yield of maize reduce significantly all over the world especially in Arid and Semi-Arid region of the world. Hence, the use of drought tolerant maize genotypes has potential to stabilize the grain yield of maize. Therefore, developing cultivars tolerant to drought stress is challenging for breeders to face the future climate changing condition. The adverse effect of drought stress on physiological and biochemical process of maize was well reported and this review is attempts which help in identify drought tolerance maize genotypes. Suitable stress tolerance index must have a significant positive or negative correlation with grain yield of maize under drought stress. Plant growth regulators, non-enzymatic antioxidants especially osmoprotectants as exogenous applications and soil application of fertilizer (organic and inorganic) can also modify the morphological, physiological as well as biochemical process of plants for better adaptation under harsh environments.

Conflict of interest

All the authors declare that there is no conflict of interest.

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