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RELATIONSHIPS BETWEEN STOMATAL CONDUCTANCE AND YIELD UNDER DEFICIT IRRIGATION IN MAIZE (*Zea mays* L.)

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KEYWORDS

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Drought stress tolerance

Stomatal conductance

ABSTRACT

This study was conducted to evaluate the adaptability of maize hybrids under water deficit condition by measuring of stomatal conductance with the corresponding yield of maize hybrids. Seven maize hybrids were grown at two different irrigation regimes (well water and deficit water conditions) at the agricultural research area of Cukurova University, Adana, Turkey. The results of study indicated that at drought stress (deficit water) remarkably influenced maize yield. The hybrid Sancia produced maximum grain yield under water deficient condition while 71May69 hybrid achieved the higher yield under well-watered condition. Stomatal conductance was strongly correlated with grain yield in this study and higher stomatal conductance indicates higher grain yield, higher stomatal conductance at 7 days after pollination helps to increase grain yield. A positive and significant correlation between grain yield and stomatal conductance was observed at 7th and 21st days after anthesis (DAA). Moderately high stomatal conductance under stress condition helps to produce the highest grain yield. Based on the results, stomatal conductance can be used as selection criterion to identify the drought stress genotypes in maize under Mediterranean condition.

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1 Introduction

Maize (*Zea mays* L.) is one of the most necessary crops for human consumption and animal feeding (Steduto et al., 2012). It is one of important plants worldwide due to its high productivity of grain and forage. It has wide adaptation properties and is intensely cultivated in Turkey. The productivity of maize is not sufficient to meet the continuous increase of consumption. Although area under maize cultivation is increasing but the total production of the maize is not sufficient in Turkey. The attempts to maximize the maize production are of great importance (Karasu et al., 2015).

Presently, drought is a main cause for the reduction of maize productivity worldwide (Banziger & Araus, 2007). Water deficit is the major factor limiting crop production (Pimentel, 2006). Therefore, the studies on irrigation and managing of water have focused on the response of crop productivity (Köksal, 2011). The development of improved breeding pipelines using a multi-disciplinary approach is essential to increase maize productivity in drought prone environment (Cairns et al., 2012a).

It is reported that some physiological traits such as stomatal conductance is a major trait which influence yield under drought stress. Bahar et al. (2009) found significant effect of stomatal conduction on wheat yield. Several researchers revealed that stomatal conductance is the complementary selection criteria for stress tolerance of crops (Dodd, 2003; Koc et al., 2008). The canopy senescence accelerates under drought condition (Wolfe et al., 1988). Some drought tolerant maize genotypes reduce leaf stomatal conductance more on the onset of drought (Ray & Sinclair, 1997). High stomatal conductance at grain filling stage would be assumed as the basic criteria for high grain yield under stressed conditions (Munjál & Rana, 2003). A non-significant correlation between stomatal conductance and grain yield of wheat was observed by Anjum et al. (2008).

Different environmental conditions and water deficit lead to increase stomatal density and reduce stomatal size, indicating adaptation of crops to drought stress (Martinez et al., 2007). Soil drying leads to an decrease in stomatal aperture and stomatal conductance (Songsri et al., 2013). The performance of the physiological processes of maize influenced under stress environment. A positive relationship between stomatal conductance and transpiration was observed by Kolb & Robberecht (1996). Further, Rahman (2005) reported that stomatal conductance is a significant selection criterion for higher yields in irrigated crops grown at supra-optimal temperatures.

Grain yield and drought adaptation are complex properties in maize breeding approach (Bruce et al., 2002). Identification of

phenotypic, ideotypes traits and donors are important in drought breeding progress (Cairns et al., 2012b). Therefore, the present research was undertaken to evaluate the effect of drought stresses on stomatal conductance and to determine the relationship between stomatal conductance and yield of maize hybrids under water irrigation regime.

2 Materials and Methods

2.1 The design of experimental and cultural practices

The study was conducted at the Cukurova University Research Farm, Adana, Turkey during 2014. The climatic data during the growing season were recorded and presented in Figure.1. The experiment was laid out in split-plot design with four replications. Seven varieties of maize hybrids viz. i) Sancia, ii) Indaco, iii) 71May69, iv) Aaccel, v) Calgary, vi) 70May82 and vii) 72May80, and (2) two irrigation regimes viz. i) Full irrigation and ii) Deficit irrigation (Water deficit) were used in this study (Figure. 1). The maize crop was grown as per recommendations. The crop was fertilized with 100 kg N and P_2O_5 ha⁻¹ (20-20-0) at planting time, and 200 kg N ha⁻¹ (Urea) at V6-growth phase.

2.2 Stomatal conductance Measurements

Stomatal conductance was measured by diffusion porometer (Model: AP4-Delta-T Eijelkamp, Giesbech, The Netherlands) on the abaxial surface of the ear leaf as mmol H₂O m⁻² s⁻¹. The measurements were completed at two times at 7th and 21st days after anthesis (DAA) with full clear air conditions at 10:00 am and 02.00 pm, nearly 1500 PAR light intensity. The relative humidity and air pressure at that time were 45% and 1000 mbar, respectively.

2.3. Calculation of drought resistance index

Drought resistance index (DRI_{SC}) was measured on the basis of stomatal conductance (SC) calculation by Fischer & Maurer (1978).

$$DRI_{SC} = (SC_s/SC_n) / (M_s/M_n),$$

Whereas, SC_s and SC_n are the genotype stomatal conductance under stress and non-stress, respectively; and M_s and M_n are the mean SC over all genotypes in the given test under stress and non-stress, respectively.

2.4 Statistical analysis

Data were analyzed by using 'analysis of variance' with the help of computer package MSTAT-C and the mean differences among the treatments were adjusted with Least Significant Test (LSD) (Fisher, 1935).

Figure 1 The temperature of research area and the quantity of applied water at the growing season (Arrow indicates pollination). (Source: Meteorological Service of Turkish State, 2016).

3 Results and Discussion

The results of investigation revealed that under control conditions the stomatal conductance was highly correlated with grain yield. The results demonstrated that genotypes with

larger stomatal conductance should be selected under optimum condition to increase productivity. A significant variation of stomatal conductance was observed among the maize hybrids. The stomatal conductance exhibited significant values under drought conditions (Figures. 2, 3).

Figure 2 Stomatal conductance of maize hybrids at 7 and 21 days after anthesis under full irrigation (Fir) and deficit irrigation (Dir) regimes.

Figure 3 Relationships between grain yield and stomatal conductance of maize at 7 and 21 days after anthesis under full irrigation (Fir) and deficit irrigation (Dir) regimes.

Different patterns of stomatal conductance were observed with irrigation regimes and also with observing dates of maize hybrids. In this research, control treatments of maize hybrids achieved higher stomatal conductance than stressed hybrids. In similar way, remarkable genotypic variations of the stomatal conductance was observed by Bahar et al. (2009). Elmetwalli et al. (2012) observed that, strong significant correlations between different sensitive index and different wheat properties during the grain filling stages. Stomatal

conductance, as a key trait of photosynthetic leaf, influenced under water stress (Jiang et al. 2006). Delay canopy senescence due to various light interceptions by the green leaf area was necessary for the productivity of hybrid maize under normal and drought stress (Cairns et al., 2012b). Several previous researches indicated that reduced canopy senescence and higher leaf chlorophyll are correlated with the increasing grain yield in well-watered temperate of hybrids (Lee & Tollenaar, 2007; Barutçular et al., 2016b).

Figure 4 Correlation between grain yield and stomatal conductance at 7 and 21 days after anthesis under full irrigation (Fir) and deficit irrigation (Dir) regimes.

The change in leaf morphology induced by deficit water caused higher reflectance in the visible spectra between stressed and unstressed corn leaves (Genc et al., 2013). A significant relationship was observed between SPAD and grain yield in 14 days after anthesis, while no significant association was found during middle and late grain-filling stages (Monneveux et al., 2008).

A large reduction in grain yield was observed in hybrids under water stress conditions. The reduction of grain yield almost equally associated with the reduction of kernels per unit area and kernel weight (data not show). Maize plants under drought exhibited significantly lower grain yield than under normal conditions (Figure. 3) and the hybrid 71May69 was produced the highest grain yield under full irrigated condition. On the other hand, Sancia hybrid produced maximum grain yield under drought condition and indicating its tolerance to drought. So, results of study revealed that environment stress (deficit-limited) remarkably influenced maize yield. This different pattern may be related to the fact that hybrids are more susceptible to water stress near anthesis and the early grain-

filling stage (Araus et al., 2010). Furthermore, Zharfa et al. (2011) also reported that the higher growth rate ability of cultivars decreases when they are exposed to water stress condition. Anthesis is considered as an important trait, when drought stresses are concerned in maize (Bänziger et al., 2002). Reduced grain yield under water stress condition in maize has been recorded by several previous studies (Cakir, 2004; Zharfa et al., 2011; EL Sabagh et al., 2015; Abd El-Wahed et al., 2015; Barutçular et al., 2016a).

Grain yield was closely and negatively associated with stomatal conductance of maize hybrids under irrigated conditions (Figure. 4). Significant and positive correlation was reported between grain yield and stomatal conductance was observed in 7 and 21 DAA (Figure. 4). In the drought environment, moderately high stomatal conductance helps to produce the highest grain yield (Figure. 3). According to the correlations of genotypes in normal environment (optimum), the high stomatal conductance indicates more grain yield, higher stomatal conductance at 7 days after pollination help to increase grain yield (Figures. 2, 3, 4).

Figure 5 Correlation between grain yield and drought resistance index (DRI_{SC}) for stomatal conductance (SC) under full irrigation (Fir) and deficit irrigation (Dir) regimes.

Grain yield was poorly correlated with root and leaf growth rates under water stress condition. Zharfa et al. (2011) reported that correlations between root growth and grain yield were higher under normal condition. The association between stomatal conductance and grain yield were observed positive correlation (but non-significant) at early milky stage ($r = 0.165$) and negative non-significant at late milky maturity stage ($r = -0.234$), while they were not found association at early water stress maturity stage (Bahar et al., 2009). A positive correlation between stomatal conductance and grain yield at early stage was observed by Bahar et al. (2009). Yield-stomatal conductance relationships become stronger in durum wheat and weaker in bread due to leaf senescence (Delgado et al., 1994).

Correlations between grain yield and drought resistance index (DRI_{SC}) was positive and significant ($r=0.784$, $P<0.037$) at 7 DAA (in the young leaves) under stressful environment. The rate of stomatal conductance varied under the stress and non-stress conditions (Figure. 5). The higher DRI_{SC} under water deficit stress indicated more resistance maize genotypes under water deficit stress and can be used as drought tolerant index in maize breeding program. Stress tolerance index (STI) is the significant trait to identify the stress-tolerant high yielding genotypes (Kharrazi & Rad, 2011; Sanjari, 2000).

Conclusions

The results indicated that water deficit stress remarkably influenced maize productivity. Under drought condition, Sancia hybrid maize produced the maximum grain yield. A negative and significant correlation between grain yield and stomatal conductance was observed at 21 DAA (in old leaves). DRI_{SC} was positive and strongly correlated with grain yield under drought conditions, high stomatal conductance (especially 7 days after anthesis) indicates more grain yield. Therefore, DRI_{SC} can be used as selection criterion to identify the drought resistant genotypes in maize under Mediterranean condition.

Conflict of interest

Authors would hereby like to declare that there is no conflict of interests that could possibly arise.

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