DETERMINATION OF DROUGHT SENSITIVITY OF MAIZE INBRED LINES VIA MONITORING CANOPY TEMPERATURE AND LEAF WATER STATUS

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Abstract

Drought is one of the most significant phenomenon that limits crop production in all around the world. Breeding drought resistant varieties is a key strategy for future agriculture production. Since global climate change has been already leading to increase frequency of drought events, limited time for breeding new varieties, more effective indirect selection techniques and useful traits for drought tolerance have received more attention. For these aspects, our study was aimed to determine drought sensitivity of maize plants by monitoring canopy temperature depression (CTD) and leaf water status. For this purpose, a field experiment was conducted with 80 maize (*Zea mays* L. Indentata) inbred lines under well-watered and short-term drought conditions during V7-9 growth stage. Plants were subjected to stress conditions for 15 day by withholding irrigation. CTD, SPAD values, leaf and soil water status was regularly monitored during stress period. The results showed that drought stress had a significant effect on CTD for all genotypes. The mean CTD values of all 80 genotypes under well-watered and drought conditions were 8.59 and 9.74 respectively. Drought treatment caused significant decrease in SPAD values of all lines. The average SPAD values at the end of the drought treatment (15th day) were 40.7 and 44.6 under well-watered and drought conditions respectively. However, no significant variation was observed between the mean values of relative water content of leaves under well-watered (83.9 %) and drought (84.3 %) conditions. Beside above given overview of the general results, response of individual inbred lines to gradually decrease in soil water content was evaluated using with regression line and its slops of the recorded physiological parameters.

Key words: Maize, drought, SPAD, DANS, RWC.

Drought is one of the most significant phenomenon that limits crop production in all around the world. The negative effects of drought depend on its severity and length. The intensity of drought stress may vary from year to year and it is closely correlated with the amount of rainfall water and the air temperatures (Soltani A. *et al*, 2001; Dalil B. and Ghassemi-Golezani K., 2012). The future predictions state that cereal demand of the world will increased by 70% by 2050 (Casaretto J.A. *et al*, 2016). Moreover the intervals between drought periods become shorter by the effects of global climate change. Currently, an increase in world surface temperature was already detected by 0.6 °C over the last century. Also it is expected that the temperature of the world will increase by 4-6°C at the end of this century (IPCC, 2013). Under this situation, more efficient usage of irrigation water reserves for irrigated crop systems such as maize is a great necessity in terms of future aspects.

Maize is a crucial cereal for human and animal nutrition. World total maize production is about 1 billion tons according to FAO, (2014). Drought related yield losses due to global warming limits the total maize production for the areas in which the maize production is practiced with rainfall irrigation. But decrease in water reserves threatens the artificial irrigated maize lands as well. Drought tolerance is known as very complex multi-genetic trait involving numerous physiological processes (Liu Y. *et al*, 2011) and conventional selection criteria such as grain yield are not useful due to their low heritability under drought condition. In other words it is difficult to select drought tolerant maize genotypes based on their grain yield potentials. These challenge, force plant breeder to use other physiological parameters such as leaf temperature which is easy to measure and informative about the severity of plant stress.

Leaf temperature is an indirect indicator of plant transpiration. Transpiration occurs on plant leaves and stomata play significant role in this event. When adequate amount of water is available in plant root zone, the stoma becomes open and allows water to vaporize from the leaf surface and leaf temperature decreases as a result of this

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process. But in case of water scarcity in soil, stomatal pores are closed and transpiration stops which result in an increase on leaf surface temperature.

Various methods and calculations were described to interpret the leaf temperature data (Dejonge K.C. *et al*, 2015). One of those methods is using plant canopy temperature (Tc) and air temperature (Ta) to identify the stress level of the plant. The difference between Tc and Ta gives useful data to quantify the water stress (Idso S.B. *et al*, 1977; Dejonge K.C. *et al*, 2015).

Relative water content of the leaves (RWC) and the SPAD values are also widely accepted parameters to measure the intensity of the drought. Number of researches stated the importance of these two traits for detecting the severity drought stress in plants. Siddique M.R.B. *et al*, (2000), stated that the relative water content and water potential decline under drought conditions. SPAD meter is a spectrodiometrical screeening technique which allows fast and non-destructive measurements in large field trials (Araus J.L. *et al*, 2012).

In the light of this information, the aims of this study were to evaluate different maize inbred lines in terms of their responses to mild term drought stress based on three physiological traits as degrees above non-stressed canopy (DANS), chlorophyll content (SPAD) and leaf relative water content (LRWC) and identify the effects of drought to these traits.

MATERIAL AND METHOD

The plant material of this research was provided form USDA (United States Department of Agriculture). Eighty inbred dent maize lines were evaluated in the field trial in 2015 maize growing season. The study was conducted at experimental fields of Ege University Faculty of Agriculture Department of Field Crops.

Field experiment was set up with 80 inbred lines in randomized complete block design with three replications. The seeds were sown into the rows of 2 m length. The spaces between rows and between plants were arranged 70 and 20 cm respectively. Each plot consisted of two rows. The compound fertilizer (15-15-15 NPK) was applied to both experiments as 90 kg N per ha with the sowing date. Remaining part of N was applied when the plants were at V5-7 stages as 180 kg N ha-1 in the ammonium nitrate form. The plots were irrigated via drop irrigation system.

The split plots were used in randomized complete block design. Drought application was used as factor A while the genotypes were used as factor B. Common irrigation practices were applied until the plants reached to V7-9 stage. After that stage drought application started and continued for 15 days. Control plots were irrigated regularly while drought plots had no irrigation during the drought application.

A fully developed youngest leaf was used at three selected plants in both drought and control plots for every genotypes. Three measurements were taken with infrared thermometer from the upper surfaces of every chosen leave. First reading was taken from the bottom part, second from the middle part and third from the tip of the leaf. Than the average of these values were used the canopy temperature (tc) for a given genotype. Temperature measurements were done every day during the drought application (15 days). To avoid the misleading effects of the air temperature changes in a chosen day, the measurements were taken between 01:00 pm and 04:00 pm for every day. To calculate the temperature depression, difference between canopy temperatures of stressed and non-stressed plants for given genotypes were found and recorded as degrees above non-stressed canopy (DANS).

SPAD values of every genotype in both drought and control plots were measured via the SPAD meter and recorded. SPAD measurements were taken in the first and the last days of the drought application.

Three plants were selected from each plot and fully developed youngest leaves were cut over the ligule. Then the leaves were weighted and recorded as fresh weight (W). Secondly the leaves were placed into the plastic buckets 1/3 full of water and the buckets were stored in a dark room with 4 Co air temperatures for a night. Than the leaves were weighted again and obtained value was recorded as turgid weight (TW). Then the leaves stayed in the drying oven at 105 Co for 24 hours and weighted lastly to take the dry weight (DW). The relative water content (RWC) was calculated by the following formula;

RWC (%) = [(W-DW) / (TW-DW)] x 100

The statistical analyses were done via MS Excell and TARIST (Açıkgöz N., 1994) statistical package program.

RESULTS AND DISCUSSIONS

Taghvaeian S. *et al*, (2014) suggested that the degrees above non-stressed canopy DANS responded to irrigation and was strongly correlated with plant measurements including leaf water potential. The DANS values of the genotypes from the 11th day of the drought treatment can be seen in Figure 1. The first ten genotypes represent the plants with the highest DANS values (stressed plants) while the second ten genotypes represent the plants with lowest DANS values (non-stressed plants) for a given day in terms of canopy temperature.

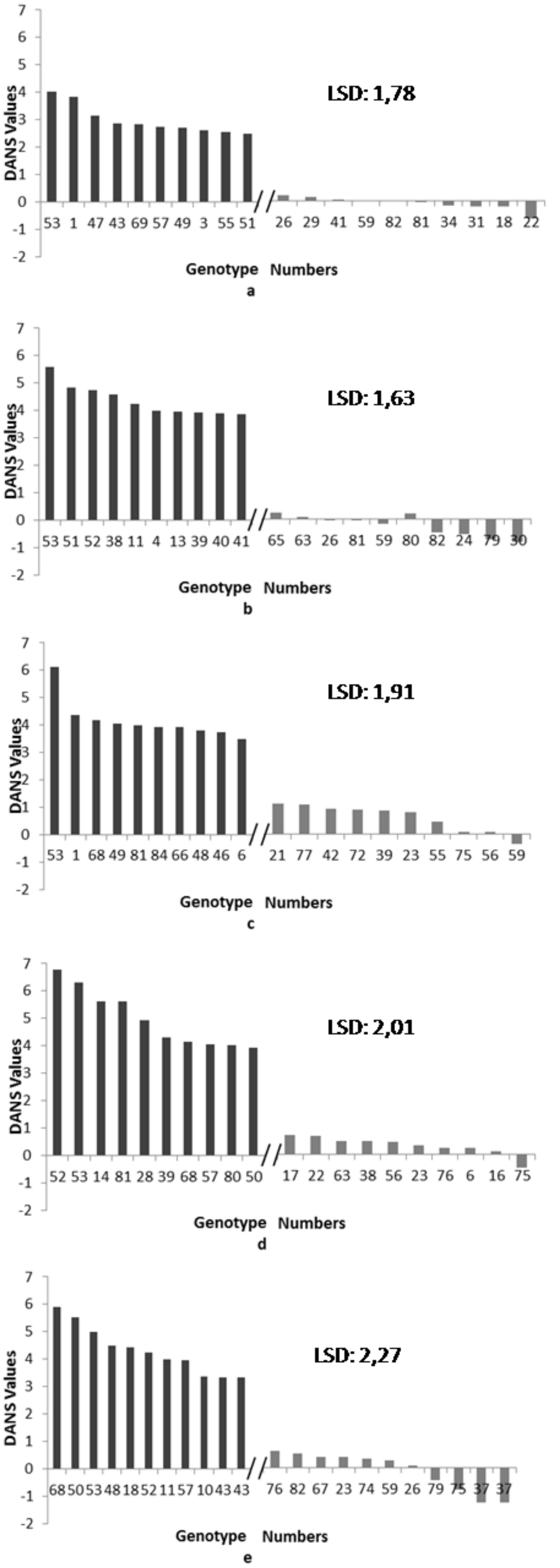

Figure 1 **DANS values of the genotypes for five days of drought treatment. a: 11th day, b: 12th day, c: 13th day, d:14th day and e:15th day of the drought treatment**

The remaining 60 plants are not shown in the figure. When examining the genotypes with highest DANS values, it was shown that genotype number 53 come into prominence as one of the most susceptible genotypes in terms of DANS values among the investigated lines (*figure 1 a*, *b*).

Genotype number 53 placed in first ten lines after the 11th day of the application. The genotype number 53 had the highest DANS values in 11th, 12th, 13th days of the drought application (*figure 1 a,b*). Besides, genotype number 75 was consistently showed lowest DANS values from the 13th day of the drought application (*figure 1 c,d,e)*.

The average relative water content values of the leaves form drought and control plots are shown in Figure *2*. No significant difference was found from the analysis of variance between the drought and control plots in terms of relative water content means.

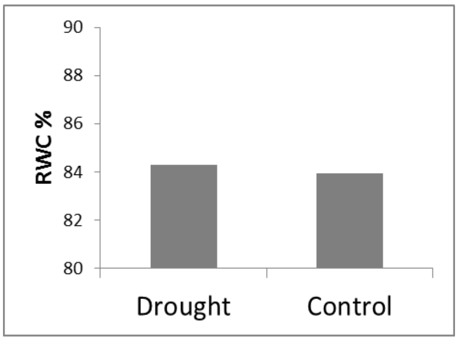

Figure 2 **Means of RWC values of drought and control plots**

Chlorophylls are one of the most important structures for photosynthesis. It was reported that the chlorophyll content is affected by negatively by the drought and the chlorophyll contents of resistant plants could be affected less from drought conditions (Khayatnezhad M. and Gholamin R., 2012; Zobayed S. *et al*, 2005). The average chlorophyll content values of drought and control plots are shown in Figure 3. Significant difference was found between drought and control plots in terms of chlorophyll contents. Figure 3shows that the plants in control plots had higher SPAD values than those of the plants in the drought plots.

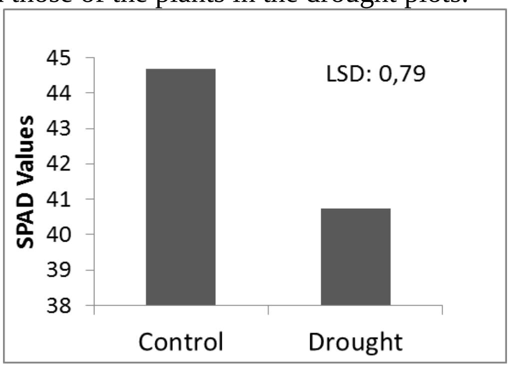

Figure 3 **Means of SPAD values of drought and control plots**

CONCLUSIONS

In conclusion it can be said that, genotype 53 come into prominence with its high sensitivity to the drought. Besides genotype number 75 had lower sensitivity to drought application with respect to DANS values. For relative water content, our drought application did not affect this trait. Lastly for SPAD values, there was a significant difference between control and drought plots which stated that the drought application has clearly dropped the chlorophyll content of the leaves.

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REFERENCES

Açıkgöz N., Akbaş M.E., Moghaddam A., Özcan K. 1994 - PC'ler İçin veritabanı esaslı türkçe istatistik paketi:TARİST, 1. Tarla Bitkileri Kongresi Bildiri Kitabı , İzmir, s.264-267.

Araus J.L., Serret M.D., Edmeades G. O. 2012 - *Phenotyping maize for adaptation to drought* Front Physiol. 2012; 3: 305.

Casaretto, J.A., El-kereamy A., Zeng B., Stiegelmeyer S.M., Chen X., Bi Y.M., Rothstein S.J. 2016 - *Expression of OsMYB55 in maize activates stress-responsive genes and enhances heat and drought tolerance*. BMC Genomics. Apr 29;17:312.

Dalil B., Ghassemi-Golezani K., 2012 - *Changes in leaf temperature and grain yield of maize under different levels of irrigation.* Res. on Crops 13 (2) : 481-485.

DeJonge, K.C., Taghvaeian S., Trout T.J., Comas L.H. 2015 - *Comparison of canopy temperature-based water stress indices formaize*, Agricultural Water Management, 156, 51–62.

FAO, Food and Agricultural Organization of United Nations, 2014 - www..fao.org/statistics. Access date: August 2016.

Idso, S.B., Jackson, R.D., Reginato, R.J., 1977 - *Remote-sensing of crop yields*. Science 196, 19–25.

IPCC, Interngovernmental Panel on Climate Change., Summary for Policymakers. 2013 - In: Stocker TF, Qin D, Plattner GK, et al., editors. Climate Change: The Physical Science Basis. Cambridge and New York: Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press; 2013. p. 1–33.

Khayatnezhad, M., Gholamin R. 2012 - *The effect of drought stress on leaf chlorophyll content and stress resistance in maize cultivars (Zea mays*). African Journal of Microbiology Research Vol. 6(12) pp. 2844-2848,

Liu, Y., Subhash C., Yan J., Song C., Zhao J., Li J. 2011 - *Maize leaf temperature responses drought: Thermal imagining and quantitative trait loci (QTL) mapping*. Environmental and Experimental Botany. Volume 71, Issue 2, June 2011, Pages 158–165

Siddique M.R.B., Hamid A., Islam M.S. 2000 - *Drought stress effects on water relations of wheat*. Bot Bull Acad Sin 41:35–39.

Soltani, A., Khooie F. R., Ghassemi-Golezani K, Moghaddam M. 2001 - *A simultaion study of chickpea crop response to limited irrigation in a semi-arid environment*. Argicultural Water Management . 49: 225-37

Taghvaeian, S., Comas L.H., DeJonge K.C., Trout T.J. 2014 - *Conventional and simplified canopy temperature indices predict water stress in sunflower*. Agr. WaterManage. 144, 69–80.

Zobayed, S., Afreen F., Kozai T. 2005 - *Temperature stress can alter the photosynthetic efficiency and secondary metabolite concentrations in St. John's Wort*. Plant Physiol. Biochem., 43: 977–984.