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Water Deficit Changes Hybrid Maize (*Zea mays* L.) Phenotypes at Vegetative Stage for Grain Yield

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Abstract: Drought and high temperature are major environmental factors that severely limit plant productivity in the World, often causing extensive economic loss to agriculture. As global climate change progresses, agricultural production worldwide faces serious threats from frequent extreme weather conditions. Integrated approaches that improve the efficiency of agricultural water use and development of plant varieties that can alleviate the negative impacts of environmental stresses to maintain yield stability are essential to sustain and increase agriculture production. Maize (*Zea mays* L.) is a major crop in the China and worldwide. Its production and yield stability are greatly affected by drought and high temperature stresses. Improving drought in maize has become one of the top priorities for maize enhancement programs in both private and public sectors. Identification of maize phenotypes with superior drought tolerance is essential and prerequisite for grain development. In this research, we evaluated ten hybrid maize lines (ZJ-009, XH-118, CM-226, BJ-337, SS-422, AH-590, HH-643, CT-713, XJ-852 & CR-911) for drought tolerance at vegetative stage under field conditions and several phenotypes were identified showed high tolerance to drought. Tolerant hybrid lines (ZJ-009, CM-226, BJ-337, XJ-852 & CR-911) were able to maintain comparatively adequate phenotypes chlorophyll fluorescence, NDVI, reduced ASI for grain yield when subjected under drought stress conditions, while sensitive lines (XH-118, SS-422, HH-643 & CT-713) showed reduction in chlorophyll fluorescence, NDVI and higher ASI. The tolerant hybrid lines also showed significantly greater ability to maintain vegetative growth and alleviate damage under drought conditions compared to the sensitive hybrid lines. Furthermore, phenotypic analysis showed that hybrid maize made from inbred lines with superior drought tolerance inherited an enhanced tolerance to elevated temperatures. The tolerant phenotypes, those identified in this study, are essential materials extract physiologically for drought tolerant for grain yield in hybrid maize. Study for the potential use of such resources to produce hybrid maize that are able to alleviate the negative impacts of drought stresses on the growth, development and grain yield of maize.

Key words: Water deficit · Grain yield · Hybrid maize · Phenotypes · Vegetative stage

INTRODUCTION

Globally crop yield decreased by biotic or abiotic stresses. Drought, flooding, heat, wind and cold are the abiotic stresses. Agriculture scientists are facing the challenge of drought in the recent situation of water shortage which may affect negatively the arable area. Drought is a serious threat for crop production and food

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security [1]. 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 fundamental function in crop production [2]. Proper phenotyping for critical primary trait and yield may help to screen stress tolerance with secondary traits are genetically correlated with yield and heritability equal or larger than the yield itself [3]. Drought stress affects water relations of plants at cellular, tissue and organ levels, causing damage and adaptation [4, 5]. Plants respond and acclimatize to survive under drought stress by the induction of various morphological and physiological responses. Drought tolerance is governed by complex genetic systems and successful enhancement programs need to consider all gene-by-gene, gene-by-environment and gene-by-development stage interactions stage interactions [6]. In drought stress important secondary traits are linked with assimilate partitioning by anthesis silking interval (ASI), ear growth and barrenness, which finally determine harvest index. The growth and emergence of silks is delayed when water stress occurs before flowering [7, 8]. When maize seedlings adjust to low water potential the walls in the apical part of root further extensible. This is due to the increase in expansion activity and some other complex phenomenon. If drought occurs at seedling stage, it enhanced adaptation for root growth of hybrid maize in drought stress. Establishment of seedling growth in early stage is very sensitive to drought. Thus execution of elongation takes places and cell stops growth and development of seedling [9-12].

During scarcity of water cell growth is severely susceptible. Stem elongation stress is reduced during vegetative stages in maize under drought condition. The green biomass normalized difference vegetative index (NDVI) which is basically proportional to the photosynthesis to determine the final grain yield. The NDVI with high accuracy could be achieved before male flowering. Therefore one measurement at a most suitable stage may be taken to reflect the drought resistance, to some extent, for vegetative stage. NDVI has newly been used for assessing green biomass & yield. The decrease of NDVI due to leaf rolling became more when plants face severe drought as observed visually [13, 14]. Chlorophyll fluorescence measurements have a broad range of application in crop or plant productivity in stress adjustment research [15-19]. Drought tolerant varieties generate more fresh and dry weights of stem as compared to sensitive one. Drought tolerant maize hybrids retain larger leaf area under drought stress as compare to drought sensitive hybrids maize. The period from one week before silking to two weeks after silking is quite important because abortion of ovules, kernels and ears may occur, during this stage [20] analyzed that water scarcity decrease the carbon availability and dry matter partitioning to ear at the critical stages and these factors determine the number of grains. When drought stress starts to affect the plant during the reproductive stage the plant reduces the demand of carbon by decreasing the size of sink. As a result drop of flowers, pollens could die and abortion of ovule may occur [21]. The abortion of ovule may take place if silks fail to extrude because of slow growth. Water deficit increase the gap between silking and anthesis effect to reduced grain filling duration of hybrids, there is a little effect on the physiological maturity of maize crop during drought stress [22]. Vegetative and reproductive stages in maize plant flowering, silking, pollination and grain formation are the sensitive stages for growth. Continuous drought at flowering stage leads to ear growth and reduces silk appearance. Anthesis-silking interval is a good indicator of movement of newly produced assimilated to the ear, cob growth, number of grains and also the water potential of plant [8]. Due to shortage of water maize crop grain yield reduced during the critical growth stages from tasseling to grain filling. Although final grain yield under drought stress is primary trait for measurement of drought resistance in crops, secondary traits are associated with selection response to drought stress conditions. Grain yield is complex trait depend on various factors such as vigorous growth, adequate water, nutrient supply, enhanced solar radiation interception and conversion to chemical energy for development [23]. Using indirect assortment of line based on phenotype strategy is an attractive approach. The aim of the present study is to investigate a single hybrid line on the basis of phenotypes obtained by drought responses among different hybrid maize lines, grain yield and on the difference in hybrid efficiency to wild type from a field experiment.

Plant Material and Experimental Conditions: The experimental work was performed at Xinjiang Agricultural Research Centre, Urumqi, Xinjiang, China. The experimental design was nested with a set of hybrid and control (wild type) in three different regimes of drought at vegetative V3 stage, drought applied at V3 stage 2-row plots (4 m row length) per line contained 30 plants per row/plot. The plots were overplanted with two seeds for each hill with three repeats was preferred. Experiment was thinned to achieve corresponding healthy density of 35000 and 40000 plants per acre for phenotypic measurements and early stand counts were recorded and the leaves were marked on selected plants to determine the growth stage during the season from hybrid lines (ZJ-009, XH-118, CM-226, BJ-337, SS-422, AH-590, HH-643, CT-713, XJ-852 & CR-911) including wild type (WT).

Calculation of Chlorophyll Fluorescence: During stress period phenotypic measurements were recorded. The dissipation of excess energy as fluorescence can be measured by a pulse-amplitude modulated (PAM) fluorometer. In general the chlorophyll content, efficiency of the photosystem II and the chlorophyll fluorescence vary along the leaf and within leaves [24]. As such it is difficult to assess a representative value for each genotype and also to assess drought stress effects on the listed traits. Thus, it is advised to combine the measurement of chlorophyll measurements with an imaging technique or with the measurement of gas exchange. The calculations were noted as chlorophyll fluorescence measurements were made with a pulse-amplitude-modulation portable chlorophyll fluorometer (Licor 6400XT and the PAM 2500, Walz, Effeltrich, Germany) suggested by Lichtenthaler *et al.* 2005; Maxwell and Johnson 2000. [24, 25].

Calculation of Vegetation Indices (Normalized Difference Vegetative Index): Different ratios and normalized indices were determined based on a combination of visible and near-infrared wavelength, as suggested by scientists [26]. Normalized Vegetation Index (NDVI) measurements were taken with the Green Seeker™ (Green-Seeker Hand Held optical sensor unit, model 505; NTech Industries, Inc., Ukiah, CA, USA). NDVI was obtained with the following equation: NDVI = (NIR-VISr)/(NIR+VISr) where, NDVI stands for normalized difference vegetation index, NIR for near-infrared radiation and VISr for visible red spectrum. NDVI values range from -1 (usually water) to +1 (strongest vegetative growth). The amount of reflectance in the NIR range (λ = 700–1300□nm) and in the VISr range (λ = 550–700□nm) is determined by the optical properties of the leaf tissues: their cellular structure and the air-cell wall-protoplasm-chloroplast interfaces [27].

Calculation of Anthesis-silking Interval (ASI): Maize is more sensitive than other cereals to water deficits and high temperatures at flowering because anthers and silks are separated by about 1 m and pollen and stigmas are exposed to the environment [28, 29]. The period in which maize is particularly sensitive to water stress is 1 week before to 2 weeks after flowering [30, 31]. When photosynthesis at flowering is reduced by drought, silk growth is delayed, leading to an increase the anthesis-

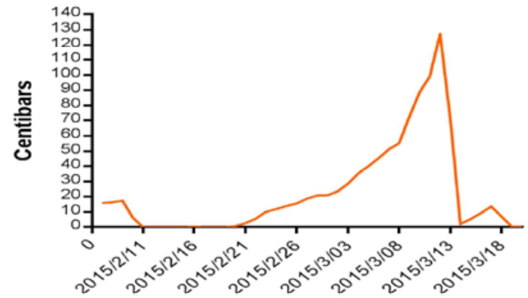

Fig. 1: Soil dryness measurements from field

silking interval (ASI). ASI days were count as difference between male & female flower (female flower 1.5 cm silk formation; male flower 30-50% pollen appears).

Yield Parameters & Drought Measurement: Yield components data 100 kernel weights (g) and plot grain yield (g) were determined by harvesting ten representative ears per plot. Soil dryness was calculated by water monitoring soil moisture inserting sensors after sowing of experiment when values reached 30 centibars the plants began to appear drought stress finally it reaches up to 140-150 centibars it was supposed to be severe drought (Fig. 1) and water was resumed normally up to harvesting, water resuming time was the condition of male flowering.

Statistical Analysis: Data were subjected to ANOVA using the general linear model (SAS Inst.), considering entries as fixed and replicates as random factors. Duncan's t-test was used to establish the mean differences between positive and negative nests. Mean differences were separated by the least significant test (LSD 0.05) when the F-tests were significant ($P<0.05$).

RESULTS AND DISCUSSION

Phenotypes Obtained During Drought Stress: Various dissimilarities including mechanisms for adaptability to water stress environments evolution for adaptation have been found in maize. In this study, significant variation has been noted for phenotypic and grain yield parameters related to drought response. The chlorophyll fluorescence (photochemical efficiency of PSII) light energy is absorbed by chlorophyll, carotenoids and other pigment molecules present in the photosynthetic antenna molecules present in the thylakoid membranes of green plants. In these results observations regarding chlorophyll fluorescence exhibited significantly ($P<0.05$) higher (0.32, 0.33, 0.31 & 0.38) chlorophyll fluorescence as compared to wild type and other hybrid lines during

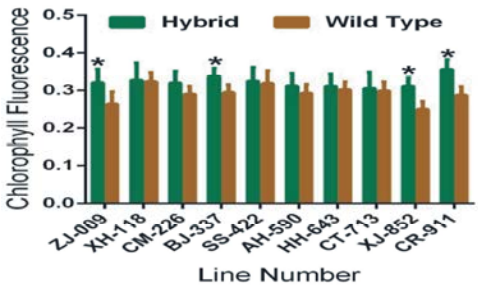

Fig. 2: Mean & standard deviation of chlorophyll florescence of different hybrid maize lines with compared to wild type.

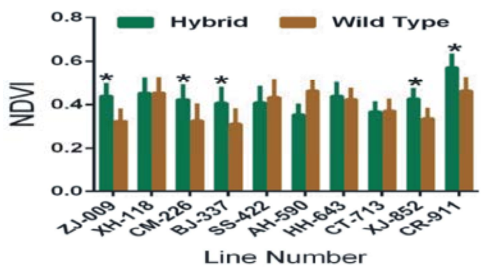

Fig. 3: Mean & standard deviation of NDVI for different hybrid maize lines as compete to wild type.

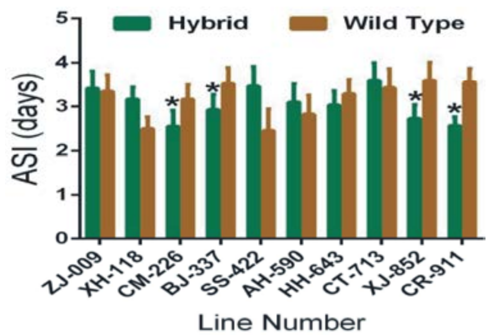

Fig. 4: Mean & standard deviation of ASI (days) for various hybrid maize lines as compete to wild type.

drought stress at vegetative stage in field, respectively (Fig. 2). Our results are associated with leaf senescence induced by drought stress in various plant species for drought tolerance (Wise and Naylor, 1987), is chlorophyll fluorescence measurements have a wide range application in crop or plant productivity estimates and in stress adaptation studies [17]. According to Lawlor and Cornic 2002. [32] decrease in relative water contents and leaf water potential decreases the speed of photosynthesis.

The green biomass can be measured as shown in this study by NDVI, which is basically proportional to the photosynthesis to determine the greenery. The decrease of NDVI measurement due to leaf rolling became more when plants with severe leaf rolling as observed visually were incorporated. Under stress condition, the NDVI decreased in the morning to the afternoon for the different hybrid maize lines with severe leaf-rolling symptom, compared to wild types and other hybrid lines. Measurement at a most suitable stage may be taken to reflect the drought resistance, to some extent, for both vegetative and reproductive stages. NDVI has newly been used for assessing green biomass & yield. Significantly ($P<0.05$) NDVI with high precision (0.42, 0.41, 0.40, 0.41 & 0.60) for (ZJ-009, CM-226, BJ-337, XJ-852 & CR-911) hybrid lines over 6 plots from each repeat was measured in several hours and thus two separate measurements of the same plant/plot was achieved in the morning and afternoon at different dates before male flowering was measured as compared to non-hybrid lines, respectively (Fig. 3). Various scientists Gamon *et al*. [33] reported that at grain filling stage NDVI decreases up to 0.3 because crop becomes under stressed and its capacity to absorb (photosynthetically active radiation) PAR is reduced. But others Royo *et al*. [34] described that NDVI score reached up to 0.4 in productive environments. Green biomass & yield are currently assessed by NDVI [13, 14].

The interval of silking & tassel formation suggested the drought tolerance at reproductive stage in field condition in the form of (ASI). The discovery of phenotype regarding ASI was significantly ($P<0.05$) sorter (2.3, 2.5, 2.3 & 2.1 days) for (CM-226, BJ-337, XJ-852 & CR-911) hybrid lines than wild types (Fig. 4). Such levels support the ASI to improve drought tolerance [35]. There was an increase of about 3 to 7 days in ASI under severe water deficiency [36].

Drought increased the interval between anthesis and silking of maize to 4.5 days from an average of 1 day under normal situation [37].

Grain Yield Obtained after Water Resuming: Grain yield is final product of plant development and each physiological mechanism involved in plant development should affect yield to unreliable degrees. The yield traits 100 kernels weight (g) was noted significantly ($P<0.05$) sufficient (31, 30.4, 29.5 & 30.4 g) (ZJ-009, BJ-337, XJ-852 & CR-911) as compared to non-hybrid and other hybrid lines, respectively (Fig. 5). According to Bismillah *et al.* 2001. [38] reduction of grains weight caused by drought stress.

The finding regarding obtained reliable grain yield in terms plot grain yield was significantly ($P<0.05$) acquired enough (133.0, 138.5, 140.0, 110.0 & 120.0 g) (ZJ-009, CM-226, BJ-337, XJ-852 & CR-911) hybrids lines as compared to w ild t ype, respectively (Fig. 6), as also

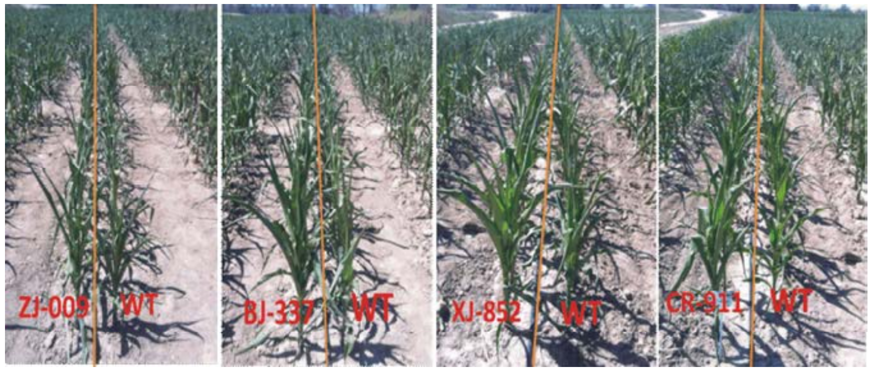

Fig. 5: Demonstration of assorted diverse hybrid maize lines (ZJ-009, BJ-337, XJ-852 & CR-911) as compared to wild types.

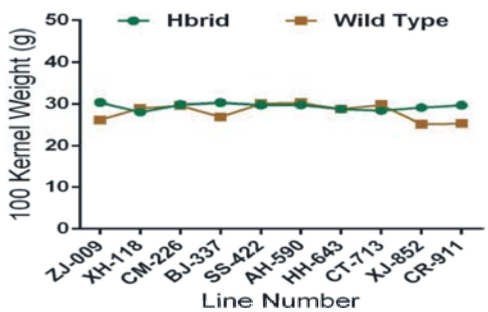

Fig. 6: Mean values showing 100 kernels weights (g) of different hybrid maize lines compared to wild type.

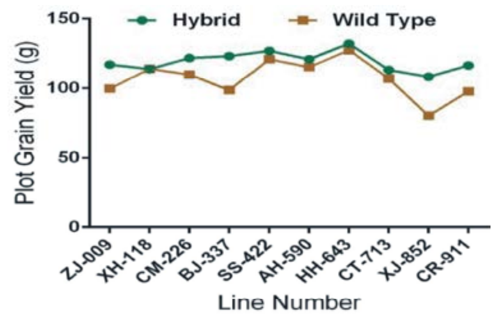

Fig. 7: Mean values illustrating plot grain yield (g) of different hybrid maize lines compared to wild type.

Fig. 8: Ears representing for different hybrid maize lines (ZJ-009, BJ-337, XJ-852 & CR-911) as compared to wild types.

seen in the study of Blum [39] suggested that yields better under drought as a important source of stress tolerance. Our findings also concern with this research regarding obtained reliable grain yield in some hybrid lines in water deficit condition. The yield-related positive effects may therefore, have environmental interactions that are probably mediated through tolerance to drought and related stresses. According to Boubacar [40] drought is one of the most critical constraint for maize productivity, regarding obtained reliable grain yield in terms of and plot grain yield (g) [41] high temperature ultimately results in yield reduction.

CONCLUSION

It can be concluded that from the results obtained from diversity of phenotypes and yield for selected hybrid maize performance in water shortage condition. Hybrid maize not only significantly improved superior phenotypes like green biomass (NDVI), higher chlorophyll fluorescence, reduced ASI are relatively comparable to each line (ZJ-009, CM-226, BJ-337, XJ-852 & CR-911) but also developed yield components including 100 kernels weight (g) & plot grain yield (g) when subjected to drought stress compared to wild type.

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