Response of some Maize Hybrids to Water Stress at Pollination Phase

Jamileh Seyedzavar and Amir Fayaz Moghadam
Department of Agronomy and Plant Breeding,
Faculty of Agriculture, University of Uremia, IRAN

(Corresponding author: Jamileh Seyedzavar)
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ABSTRACT: In order to evaluation the response of some maize hybrids to water deficit stress, a field experiment in 2010 with maize hybrids was conducted using a split-plot plan with complete randomized block design in four replications at the agricultural research station, university of Tabriz (Khalatpoushan). Main plots included three different irrigation regimes (Non-Stress, Mild-stress and Severe-stress) and sub plots included 14 maize hybrids. Results showed significant differences among hybrids and irrigation regimes for all studied traits. Analysis of variance revealed significant differences between Hybrids and also irrigation levels for all traits. In the present study, grain yield had a positive-significant correlation with number of tassel branches and number of leaves per ear. This research suggests that there is considerable variation among studied hybrids in water stress at pollination stage. Since anthesis was found as the highest sensitive stage to water stress, to avoid high grain yield reduction, favorable soil water condition must be provided in irrigation schedual.

Keywords: water stress, pollination stage, maize, grain yield.

INTRODUCTION

Corn (Zea mays L.) is one of the important cereal crops in the world and Iran after wheat and rice (Alvi et al., 2003; Gerpacio and Pingali, 2007). Maize crop plays an important role in the world economy and is valuable ingredient in manufactured items that affect a large proportion of the world population (Alvi et al., 2003). Corn is produced primarily for animal feed and industrial uses and it is portioned as follow; about 35% for human nutrient requirement and about 65% for animal feed (Kusaksiz, 2010). Corn is used as food and feed for livestock and meets the requirements of material in different industries such as food, medicine and textile (Ali et al., 2011).

Selection is a widely used and successful method in plant breeding. Response to selection depends on many factors such as the interrelationship of the characters. Plant breeders work with some yield components related to yield in the selection programs and it is very important to determine relative importance of such characters contributing to grain yield directly or indirectly (Joshi, 2005).

Grain yield is a complex trait that is influenced by a large number of physiological processes. These processes are manifested in growing, morphological and physiological traits, and these traits are measurable (Hobbs and Mahon, 1982). Studies evaluating direct and indirect effects on yield components associated with the heritability, can significantly improve the efficiency of breeding programs through the selection indices (Kashiani et al., 2010).

It is a "single most common cause of severe food shortage" (FAO) in developing countries and predicted global warming in XXI century will increase drought impact on crop production. Drought can be defined as the absence of adequate moisture necessary for normal plant growth and to complete the life cycle (Zhu, 2002). Estimations of Intergovernmental Panel on Climate Change (IPCC, www.ipcc.org) are that between 1990 and 2100, global increase of temperature will be 1.4 to 5.8 °C. Although the effect of this warming will be regionally distributed, it is assumed that increase in temperature, reduction in rainfalls, together with increase of incidents of insects and pests will reduce crops grain yield, particularly in tropical and subtropical area (Ribaut, 2006).

Drought stress is considered one of the most common factors of limiting plant growth in arid and semiarid regions (Turhan and Baser, 2004). Drought pressure was classified as one of the most deleterious environmental stresses which restrict crop production (Alahdadi et al., 2011; Khodarahmpour, 2011; Oraki et al., 2011; Song et al., 2010; Sinaki et al., 2007) and 20-25 percent of the planting area of maize is affected by drought pressure in the world (Golbashy et al., 2010).
Variation in water availability (interannual or intraseasonal) is the prevalent limitation to crop production systems in most regions of the world-over 80% of total global agricultural land is rain field (Easterling et al. 2007). Security of food in the world relies on growth and development of plants which are highly tolerated to abiotic stresses particularly drought (Ali et al., 2011 and Jaleel et al., 2009). Currently selection criteria are applied for good variety selection as compare to breeding techniques which are time consuming (Zhu, 2002). The effect of temperature (and drought) in reducing the length of the growth cycle, especially the grain filling phase, is the most important factor in explaining reduced yields at warmer temperatures (White & Reynolds 2003). It is a fact that 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 of it tillers degenerate, flower may drop, pollen may die and ovule may abort (Blum, 1996).

The flowering and pod setting stages appear to be the most sensitive stages to water stress. Researches indicated that water deficit during reproductive growth was more effective than that during vegetative growth of rapeseed (Nayyar et al. 2006; Ghobadi et al. 2006). Heat or drought stress during the maize silk-tasseling phase (flowering and pollination) have been observed to reduce yields by as much as 7% per day of stress, a greater yield reduction than for all other potential climatic stresses (Shaw 1977). Khodarahmpour and Hamidi (2012) showed that the grain yield reduced 15, 40, and 60 percent respectively due to stress during at the vegetative growth, pollination and grain filling. Similarly, increased temperatures (and deficit of water) during a plant's reproductive period, when grain filling occurs, indirectly cause yield reductions. Yields are significantly correlated with the duration of the reproductive period (correlation of r = 0.81; Cross, 1975). Limited irrigation at critical stages of growth and development may be crucial for recognition of tolerant maize varieties. Thus, the objective of this research was to evaluate the performance of maize cultivars under water deficit stress at pollination stage.

**MATERIALS AND METHODS**

A split plot experiment (using RCB design) with four replications was conducted in 2010 at the Research Farm of the Faculty of Agriculture, University of Tabriz, Iran, in order to determine response of some corn hybrids to water stress. Irrigation treatments (NWS: non-water stress, MWS: middle water stress and SWS: severe water stress) were located in main plots and 14 corn hybrids were allocated to sub plots. The name of hybrids was: SC700, SC704, KSC705, SC706, SC702, SC670, SC647, SC604, K166 × K18, DC370, K48 × K19, SC500, K3647 × K18 and SC400

Seeds of corn hybrids were sown by hand on 6 June 2010. Different water stress treatments (I1, I2 and I3; 40, 70 and 120 mm evaporation from class A pan, respectively) applied after completing the pollination. Several morphological traits were measured under control and water stress conditions. Data were recorded on 10 competitive plants of each plot and grain yield (kg ha⁻¹) and yield component was calculated for the entire plot. Some of the studied traits were:

- Length of silk (LS)
- Length of tassel (LT)
- Number of tassel branches (NTB)
- Number of leaves per ear (NLE)
- Grain depth in cob (GDC)
- Grain width (GW)
- Cob diameter (CD)
- Grain yield per plant (GY)

All the data were analyzed on the bases of experimental design, using SAS 9.1 software. Duncan multiple range test was applied to compare means of each trait at 5% probability.

**RESULTS AND DISCUSSION**

Analysis of variance of the data for yield and yield components of maize cultivars showed that Length of silk (p < 0.01), length of tassel branches (p < 0.01), number of tassel branches (p < 0.01), number of leaves per ear (p < 0.01), grain depth in cob (GDC), grain depth (p < 0.01), cob diameter (CD) and grain yield per plant (p < 0.01) significantly affected by drought stress (Table 1).

Means of all traits except cob diameter were decreased under water stress. Because of water deficit cob diameters increased. (Table 2). Pandy et al. (2000) reported that, deficit irrigation in reproductive stage plenty reduced most of yield component traits. In the total SC702 had the lowest dimension of grain (Fig. 1 and Fig. 2) and had the highest cob diameter under average stress condition (Fig. 3).
Table 1: Analysis of variance for studied traits under water stress at pollination stage.

<table>
<thead>
<tr>
<th>S.O.V</th>
<th>df</th>
<th>LS (Cm)</th>
<th>LTB (Cm)</th>
<th>NTB</th>
<th>NLE</th>
<th>GDC (Cm)</th>
<th>GW (Cm)</th>
<th>CD</th>
<th>Grain yield (gr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Replication</td>
<td>3</td>
<td>1.808 ns</td>
<td>41.505 ns</td>
<td>5.304**</td>
<td>2.122 ns</td>
<td>0.006 ns</td>
<td>0.004 ns</td>
<td>0.007 ns</td>
<td>6405.96**</td>
</tr>
<tr>
<td>Stress</td>
<td>2</td>
<td>9.566**</td>
<td>129.701*</td>
<td>217.2**</td>
<td>20.76**</td>
<td>0.051*</td>
<td>0.033*</td>
<td>0.363**</td>
<td>60390.2**</td>
</tr>
<tr>
<td>Error1</td>
<td>6</td>
<td>1.404</td>
<td>17.662</td>
<td>0.179</td>
<td>4.79</td>
<td>0.005</td>
<td>0.005</td>
<td>0.011</td>
<td>717.67</td>
</tr>
<tr>
<td>Hybrid</td>
<td>13</td>
<td>19.471**</td>
<td>52.397**</td>
<td>45.83**</td>
<td>11.77**</td>
<td>0.030**</td>
<td>0.024 **</td>
<td>0.108*</td>
<td>6720.58**</td>
</tr>
<tr>
<td>Hybrid*Stress</td>
<td>26</td>
<td>1.052 ns</td>
<td>0.024 ns</td>
<td>4.128 ns</td>
<td>0.67 ns</td>
<td>0.001 ns</td>
<td>0.001 ns</td>
<td>0.026 ns</td>
<td>673.18 ns</td>
</tr>
<tr>
<td>Error2</td>
<td>117</td>
<td>1.429</td>
<td>5.545</td>
<td>5.78</td>
<td>0.609</td>
<td>0.005</td>
<td>0.008</td>
<td>0.056</td>
<td>797.15</td>
</tr>
<tr>
<td>CV (%)</td>
<td></td>
<td>12.22</td>
<td>5.61</td>
<td>13.51</td>
<td>8.21</td>
<td>7.08</td>
<td>6.62</td>
<td>8.68</td>
<td>18.19</td>
</tr>
</tbody>
</table>

ns.*, **: non-Significant. Significant at 0.05 and 0.01 probability level, respectively.

Table 2: Comparison of means of yield component and grain yield of maize under water stress at pollination stage.

<table>
<thead>
<tr>
<th>Treats</th>
<th>LS (Cm)</th>
<th>LTB (Cm)</th>
<th>NTB</th>
<th>NLE</th>
<th>GDC (Cm)</th>
<th>GW (Cm)</th>
<th>CD (Cm)</th>
<th>GY (Gr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-stress</td>
<td>10.141a</td>
<td>43.351a</td>
<td>19.735a</td>
<td>10.114a</td>
<td>1.041a</td>
<td>0.836a</td>
<td>2.683 b</td>
<td>188.655a</td>
</tr>
<tr>
<td>Middle stress</td>
<td>9.878 a</td>
<td>42.050b</td>
<td>17.855b</td>
<td>9.5108b</td>
<td>1.030 a</td>
<td>0.848a</td>
<td>2.721b</td>
<td>153.799b</td>
</tr>
<tr>
<td>Severe stress</td>
<td>9.331c</td>
<td>40.317c</td>
<td>15.798c</td>
<td>8.896c</td>
<td>0.984 b</td>
<td>0.815b</td>
<td>2.838 a</td>
<td>123.020c</td>
</tr>
</tbody>
</table>

Fig. 1. The comparison of the grain width in the average levels of water deficit.

Fig. 2. The comparison of grain depth in the average levels of water deficit.
Removal of leaf and tassel reduces yield and grain number. Corn tassel is an organ that after pollination absorbs 20-40% of intercepted radiation at high densities and decreases the radiation intercepted by leaves (Dungan and Hatfield, 1965). In the present study hybrids K166xK18 and SC500 had the maximum number of tassel branches and hybrids SC704, SC702 and SC647 had the minimum of that (Fig. 4).

**Fig. 3.** The comparison of the cob diameter in the average levels of water deficit

**Fig. 4.** The comparison of the number of tassel branches in the average levels of water deficit.
Optimal leaf area establishment is vital criterion for photosynthesis maintenance and dry matter production. Photosynthetic pigments are used specially for capturing light and reducing powers production (Farooq et al., 2009). Photosynthesis directly depends on relative water contents and leaf water potential. Decrease in relative water contents and leaf water potential decreases the speed of photosynthesis (Lawlor and Cornic, 2002). In this study hybrids SC500, K3647xK18 and SC400 had the highest number of leaves per ear and hybrids SC700, SC704 and KSC705 had the lowest of that (Fig 5).

Due to shortage of water to maize crop grain yield reduced if water deficit occurs during the critical growth stages from tasseling to grain filling. Drought stress before one week to silking and two weeks after silking decreased the grain yield (53% of the non-drought stressed) (Classen and Shaw 1970). Maximum grain yield under average stress condition was showed in SC500 against of SC704, KSC705, SC702, SC647 (Fig. 6).

Obviously reducing the grain width and depth leads to reduction in size and weight of the grain. Water stress in maize because of the leaves wilting, cause to reduced photosynthesis and photosynthetic material transfer. This action by prevent from grain development, finally reduced grain weight (Nelson, 2003). Mojadam (2006) concluded that grain yield, dry matter of ear, cob, stem, leaves, plant height, and ear length significantly reduced in response to water deficit stress. Alavi Fazel and Lak (2011) reported that the highest grain yield was obtained at the optimum irrigation and grain yield reduced up to 35 percent due to stress at the pollination. Payero et al. [26] showed that drought stress significantly decreases the maize grain yield. Frederick et al. (2001) reported that, drought stress happening between initial flowering and grain fill decreases total grain yield primarily by reducing branch vegetative growth, which reduces branch grain number and branch grain yield.

In the present study, grain yield had a positive-significant correlation with number of tassel branches (0.888) and number of leaves per ear (0.765) (Table 3). Setter et al., (2001) stated that water stress at pollination stage affected grain formation process in the corn through reducing leaves photosynthesis and reduced the number of grain per ear due to increasing the production of sterile pollen which was resulted from assimilate deficiency. Dry weight loss and reduce of photosynthetic materials due to water limitation have also been reported by other researchers such as Osborne et al. (2002). The increment of dry mater is because of higher use of light due to expansion of leaf area under normal irrigation (irrigation after 70 mm evaporation) condition. Lak et al. (2007) also emphasized that reduction in plant dry matter production under irrigation after 130 mm evaporation due to the negative impact of drought stress on ear dry weight (51% reduction) because in corn, cob is an important component of the plant. Scarisbrick and Daniels (1986) showed that 20% of total dry matter weight could be reduced because of drought stress during flowering period.
Water stress around flowering and pollination delays silking, reduces silk length, and inhibits embryo development after pollination. Moisture or heat stress interferes with synchronization of pollen shed and silk emergence (Valliyodan and Nguyen, 2006). Abdelmula and Sabiel (2007) showed that Plant height, leaf area and number of leaves per plant were positively correlated with grain yield. They found that Plant height, number of leaves per plant and stem diameter might best selection criteria for improvement in maize.

Yield reduction in hot and dry condition is due to physiological stress, rather than the sensitivity of plant phenology to temperature. Fertilization necessitates a temporal overlap between the shedding of pollen by tassel and the emergence of silks (to intercept the pollen). Hot and dry weather both hastens pollen shed and delays silk emergence, narrowing the duration of co-occurrence. In addition, the ability of pollen to germinate on silks is greatly reduced at temperatures above 32°C (Basra 2000). The result is fewer grains available for filling during the reproductive period that directly follows (Herrero & Johnson 1980). Although climatic factors can cause severe yield reductions, their effects on silk-tasseling are difficult to identify because of the short duration of the period (Porter & Semenov 2005).

Considering the results of this research which are consistent with those of Oktam (2008), deficit irrigation reduced the yield, so that deficit irrigation and supplying 80 and 60 percent of full irrigation. In severe stress, stomata were closed which in turn reduced the uptake of carbon dioxide and the dry matter production, and the continuance of stress led to drastic reduction of photosynthesis. It seems that the reason of dry matter reduction under deficit irrigation, is mainly due to less leaf area expansion which did not provide a sufficient physiological source for absorbing more light and dry matter producing. These findings confirmed the researches of other researchers who reported that drought stress reduced the biological yield (Classen and Shaw, 1970; Alizadeh et al., 2008; Alavi Fazel and Lak 2011).

Table 3: Correlation coefficients between the traits of maize hybrids in moderate levels of water stress

<table>
<thead>
<tr>
<th>Traits</th>
<th>LS(Cm)</th>
<th>LTB(Cm)</th>
<th>NTB</th>
<th>NLE</th>
<th>GDC(Cm)</th>
<th>GW(Cm)</th>
<th>CD(Cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LTB (Cm)</td>
<td>0.826**</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NTB</td>
<td>0.136 ns</td>
<td>0.265 ns</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NLE</td>
<td>0.703**</td>
<td>-0.316 ns</td>
<td>0.599*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GDC(Cm)</td>
<td>0.560*</td>
<td>0.606*</td>
<td>0.432 ns</td>
<td>0.156 ns</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GW(Cm)</td>
<td>0.535*</td>
<td>0.800**</td>
<td>0.539 ns</td>
<td>-0.174 ns</td>
<td>0.609*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CD(Cm)</td>
<td>-0.575*</td>
<td>-0.737**</td>
<td>-0.093 ns</td>
<td>0.126 ns</td>
<td>-0.515 ns</td>
<td>0.598*</td>
<td></td>
</tr>
<tr>
<td>GY(Gr)</td>
<td>-0.163 ns</td>
<td>0.264 ns</td>
<td>0.888 **</td>
<td>0.765 **</td>
<td>0.601*</td>
<td>0.482 ns</td>
<td>-0.213 ns</td>
</tr>
</tbody>
</table>

ns , *, **: non-Significant, Significant at 0.05 and 0.01 probability level, respectively.

CONCLUSION

According to the results of this research deficit irrigation based on 80% of full corn water requirement could be recommended under dry year's condition with lower grain yield reduction. Since anthesis was found as the highest sensitive stage to water stress, to avoid high grain yield reduction, favorable soil water condition must be provided in irrigation schedule.

REFERENCES


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