



Research Article

The Effect of Iron and Molybdenum Spray on Maize (S.C. 704 cultivar) under Different Water Status Conditions

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ABSTRACT

In order to evaluate the effects of micronutrient application on yield properties of maize in response to drought stress at flowering stage an experiment was conducted at research farm of Sari Agricultural Sciences and Natural Resources University during the cropping season of 2014. The experiment was laid out in factorial arrangement based on completely randomized block design with three replications. The two irrigation regimes were used (40% and 70% of water evacuation based on field capacity, respectively as normal irrigation and stress treatment), and also spray application of micronutrient (water as control Fe, Mo and Fe + Mo) were considered as the second factors. Drought stress and micronutrient sprays were significantly affected grain yield and some yield components of maize. Throughout the different spray of microelements the maximum positive effects on plant heights was belong to Fe + Mo spray treatment (with 193 cm). Drought stress was extremely induced reduction in grain numbers per row (26.5%) as compared to normal irrigation. Water limitation was lead the high decrease in grain number per each ear (28% reduction) compares to normal irrigation. Also between micronutrient spray the maximum grain number per year was related to Fe + Mo foliar application and the lowest was obtain from control treatment (water spray). Highly reduction in grain yield through the stress condition (more than 30% compared with normal irrigation) was observed. Among micronutrient sprays the highest positive effects on final grain yield (with 12211.5 kg h⁻¹) was related to Fe + Mo treatment which was significantly higher than control (water spray) (more than 42%). It could be concluded that vegetative growth properties (plant height and biological yield) and also reproductive parameters were strongly affected by water stress. Nevertheless, between all studied parameters the highest reduction was appeared in final grain yield. Totally plant height as vegetative growth parameter and number of grain per row as reproductive properties due to their response to water shortage and micronutrient sprays could play a key roles for estimation of maize yield losses at the similar condition.

Key words: Grain yield, maize, Micronutrient, Water shortage

INTRODUCTION

From the past to present, maize (*Zea mays* L.) is the staple food for the millions of people consumption, and its production is essential for food security at the global level (Campos, et al. 2011). Water as a vital element is the most valuable and yet scarce commodity in our planet. It constitutes 90% of living organisms and covers about 75% of the Earth's surface. Hence, the agricultural productivity is highly dependent upon water and it is required during all phonological stages of plants growth,

from seedling emergence to maturity (Turner, 1991). Availability of water is the major limiting factor in crop production, especially in semi-arid regions. Drought as a meteorological term takes place when moisture losing from the soil surface more than water supplies from the resources (in the form of rainfall or other sources of precipitation). Drought is the main threat to plant production. Water potential and turgor pressure of the cells are decreased during the water deficit and this condition disturbs the normal functioning of plant physiological mechanisms (Hsiao, 1976). These changes

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induced different effects on growth and yield parameters of the crops (Reisdorph and Koster, 1999). Results from many studies about water stress affects plant yield properties for instance grain yield in maize (*Zea mays* L.) (Ebrahimian and Bybordi, 2011); growth and productivity reduction in sunflower (*Heliantus annuus* L.) fresh and dry weights decline in shoot and flowers of marigold (*Tagetes erecta* L.) plants (Asrar and Elhindi 2011); shoot and root dry weights reducing in Asian red sage (*Salvia miltiorrhiza* L.) (Liu et al. 2011); yield reduction due to limited growth duration in bread wheat (*Triticum aestivum* L.) (Abbas *et al.* 2009); have been well documented.

Crops respond to drought stress by different ways. For instance, flowering times in maize (Abrecht and Carberry 1993) and rice (*Oryza sativa* L.) (Fukai 1999) is delayed upon exposure to drought, while in soybean (Desclaux and Roumet 1996), wheat, and barley (McMaster and Wilhelm, 2003) drought stress accelerate the flowering and physiological maturity. Drought stress imposes osmotic stress leading to loss of turgor and oxidative stress through production of reactive oxygen species (ROS) that results loss of membrane integrity, protein degradation, and oxidative damage to other biomolecules. As a consequence of such changes, inhibition of photosynthesis, metabolic dysfunction, and damage to cellular structures occur causing growth perturbances, reducing fertility, and premature senescence (Munns and Tester, 2008).

C4 plant due to the presence of a well-defined bundle sheath, chloroplast dimorphism, two carboxylation pathways involving, phosphoenolpyruvate carboxylase (PEPC) in mesophyll and ribulose 1,5-bisphosphate carboxylase (RUBISCO) in bundle sheath cells have distinctive leaf anatomy in compare to C3 plants, so maize as a C4 crop needs more nutrients and water resources from soil during its growth period. Our region (Iran) is located in arid climate with calcareous soils, and high pH and mean temperature, plants mostly affected by different abiotic stresses. In Iran drought stress is the main limiting abiotic factor and its which restrict crop production and decline the use efficiency of dry and semi dry lands. Consequently diagnosis and utilization the special improvement methods to inducing drought tolerance or using new strategies to reduce the detrimental effects of drought stress in plants, may be convert semi-arid to arable regions (Wesely et al., 2002). Plants respond differently to water deficiency in different periods of their growth. The generative phase and the beginning of flowering are most frequently the period of the greatest sensitivity to water deficit, especially in corn production. The aim of the present study was to investigate the response of maize in term of yield and yield components to foliar spray of micronutrient (Fe and Mo) under drought condition.

MATERIALS AND METHODS

In order to evaluate the effects of micronutrient application on yield properties of maize in response to drought stress at flowering stage an experiment was conducted at research farm of Sari Agricultural Sciences and Natural Resources University during the cropping

season of 2014. The field area was 500m² and also was not cultivated during the previous year (under follow system). Soil sampling was done before sowing and physical and mechanical properties of field soil were analyzed according to the table 1.

Uniform maize seeds of single cross 704 hybrid after removing the trashes and impurities were selected and hand-shown early in June with 50-cm rows. The plants were 10 cm apart within each row in plot of 3 m wide and 5 m long. The experiment was laid out in factorial arrangement based on completely randomized block design with three replications. The two irrigation regimes were used (40% and 70% of water evacuation based on field capacity, respectively as normal irrigation and stress treatment), and also spray application of micronutrient (water as control Fe, Mo and Fe + Mo) were considered as the second factors.

Urea and ammonium phosphate were applied as nitrogen and phosphate sources at 350 kg/ha⁻¹ and 250 kg ha⁻¹, respectively. Also the plots were regularly hand weeded. The two irrigation levels consist of 40% and 70% of water evacuation based on field capacity replacement according to evapotranspiration (ET) losses during silking stage (R1). The plots were irrigated by tape irrigation method and the applied water amounts were controlled by water meters and the following equation:

$$\text{Equation 1: } d = (FC - \theta) D / 100$$

Where, FC% = field capacity; θ = soil moisture content; D_{cm} = soil depth; d_{cm} = irrigation water depth

The micronutrient sprays were applied three times based on morpho-physiological characterization of maize, in ear and tassel initiation (V6), tassel emergence (VT) and silking (R1) stages, respectively. During foliar application by sprayer to avoid the drift of solutions the plot was surrounded by polyethylene. Maize was manually harvested completely from each plot (15 m²) at full physiological maturity of kernels (65-70% dry weight). Total grain yields after drying in oven (65°C for 72h) were adjusted to 14% moisture content. Harvest index (HI) by dividing the total grain yield on total biomass was calculated:

$$\text{Equation 2: } HI = (GY/BM) \times 100\%$$

Where, GY = grain yield and BM = biomass

Statistical analysis

Analysis of variance was performed for studied traits by using the general linear model (PROC GLM) procedure in Statistical Analysis System (SAS) and the mean comparisons were evaluated based on Least Significant Differences (LSD).

RESULTS AND DISCUSSION

Drought stress and micronutrient sprays were significantly affected grain yield and some yield components of maize. However, the interactions were not statistically significant between studied parameters with the exception plant height (table 2).

Plant height

Plant height as an important growth characteristic could be helpful in determination of growth attained during the growing period. During the maize vegetative growth stage, plants were highly affected by water availability and micronutrient application which directly become visible at plant height variations (table 3). According to the results drought stress severely impressed the plants height so that the plants which were exposed to water limitation showed highly reduction in height compare to normal condition (17% reduction). Throughout the different spray of microelements the maximum positive effects on plant heights was belong to Fe + Mo spray treatment (with 193 cm) (table 4).

The minimum reduction in plant height was obtained when the Fe+Mo treatment was applied (13%) and the highest reduction rate was related to control treatment (water spray) with 21%. Elongation of stem in maize under drought stress was reduced during vegetative stage it may be due to severe sensitivity of cell growth to water deficit conditions (Sharma and Bhalla, 1990). Cakir (2004) suggested that water deficits could significantly induced limitation in maize vegetative growth stages which ultimately leads to reduced plant height.

Number of grain per row

The importance of grain number in plant final performance especially in corn production was investigated by many authors; most of them (Yazdandoost, 2000; Pourmeidani, 1998; Ramee, 2000) suggested the directly positive relation between grain numbers per row and final yield. However, only some of them believed that the number of grain per row could negatively influence the plants final performance. The average number of grains per row was significantly affected by irrigation levels and micronutrient application (table 2). According to the results obtained from mean comparison (table 3), drought stress was extremely induced grain numbers reduction per row (26.5%) in compare to normal irrigation (table 3), between micronutrient sprays the number of grain per row was related to both Fe and Fe+Mo with 34.1 and 37.1 grain numbers respectively. One of the major environmental reduction factors in crops yield worldwide is drought (Vincent et al. 2005). Water deficit occurs in environment when uptake of water through the roots of plants is insufficient to meet the water requirement for unhindered growth, transpiration and photosynthesis in shoot (Fan et al. 2006). Water deficit reduces water potential and turgor pressure in plant which lead to difficulty in performing normal physiological function especially during the reproductive period (Lisar et al. 2012).

Number of grain per ear

In development stages of maize, the period from 10 days before silking to 15 days after silking is very important because abortion of ovules, kernels and ears may occur. Drought stress during this period initiates damages to this process. Our results showed that, number of grain in each ear could be influenced extremely by drought stress (table 3). Water limitation was lead the high decrease in grain number per each ear (28% reduction) compares to normal irrigation. Also between

micronutrient spray the maximum grain number per ear was related to Fe + Mo foliar application and the lowest was obtain from control treatment (water spray). Andrade et al. (1999) suggested that water shortage decrease the carbon availability and partitioning the dry matters to ear at this exigent period (silking) and these factors are crucial in seed formation and final number of them in each ear. Actually, when drought stress starts to affect the plant during the reproductive stage the plant reduces the request of carbon by limiting the size of sink. As a result of it tillers degenerate, flower may drop, pollen may die and ovule may abort (Blum, 1997). The inherently characters of maize may have more potentials for ears, ovules and kernels as compare to produce at the time of maturity (Tollenaar and Wu, 1999).

1000 grain weight

1000- Grain weight is an important yield contributing factor, which plays an important role in showing the potential of a crop variety. The average weight of 1000 grain weights in ranges 221-220 gr was recorded and its statistically analysis reveals that water limitation and micronutrient spray couldn't significantly affected 1000 grains weight. However the highest 1000 grain weights was obtained when the plants treated by Fe + Mo foliar spray (220gr). Since the high genetically dependence of grain weight to the variety, this factor affected in lower range by drought stress and foliar application of micronutrients compared with other yield properties.

Grain yield

Grain yield is a final performance which resulted by integrated effects of many complex morpho-physiological processes occurring during the growth and development of a crop. Due to water deficit in maize crop grain yield reduced if water limitation occurs during the critical growth stages from tasseling to grain filling. Data of mean comparison as influenced by drought stress and micronutrient spray that are given table 3 showed highly reduction of grain yield through the stress condition (more than 30% compared with normal irrigation). Among micronutrient sprays the highest positive effects on final grain yield (with 12211.5 kg h⁻¹) was related to Fe + Mo treatment which was significantly higher than control (water spray) (more than 42%). Bergamaschi *et al.* (2004) indicated that drought Stress during critical growth period reduced the grain yield up to 2 t/ha. Dai *et al.* (1990) reported that mild water stress inhibited the growth and development of all the hybrids at different growth stages maize crop and also had effect on yield. Among various abiotic stresses, drought is one of the major environmental constraints limiting crop productivity worldwide (Masoumi et al. 2010; Khamssi et al. 2011; Batlang et al. 2013). About 25 % of the world's agricultural land is affected by drought stress (Jajarmi 2009). Maize production is highly depended on availability (variability) and quality of natural resources, principally waters and nutrients. When maize encounters water deficit, there is decline in photosynthesis functioning per plant this can be due to a reduction in light interception as leaf expansion is reduced or as leaf senesce and to reductions in C fixation per unit leaf per area as stomata close or as photo-oxidation damages the photosynthesis mechanisms.

Table 1: physical and mechanical properties of field soil

| Depth | Texture | EC _{ds/m} | pH | T.N.V% | O.C% | P _{ppm} | K _{ppm} |
|--------|-----------|--------------------|-----|--------|------|------------------|------------------|
| 0-30cm | Clay silt | 1.4 | 7.5 | 19.3 | 3.48 | 12.3 | 367.3 |

Table 2: Analysis of variance on growth, yield and yield components of maize cultivar (SC 704) under drought stress

| SOV | df | Plant height | Number of grain per row | Number of grain per ear | 1000 grain weight | Grain yield | Biological yield | Harvest index |
|--------------------------|----|--------------|-------------------------|-------------------------|----------------------|-------------------------|-------------------------|---------------------|
| Status of irrigation (a) | 1 | 2904.0** | 574.28** | 141557.7** | 274.05 ^{ns} | 80320538.76** | 290179294.4** | 10.14 ^{ns} |
| Micronutrient spray (b) | 3 | 558.50** | 106.99** | 30599.8** | 61.28 ^{ns} | 17341884.55** | 43812750.5* | 26.51 ^{ns} |
| a×b | 3 | 63.00* | 2.37 ^{ns} | 461.71 ^{ns} | 3.31 ^{ns} | 192578.91 ^{ns} | 5320655.4 ^{ns} | 57.99 ^{ns} |
| Error | 16 | 13.85 | 9.65 | 2312.70 | 117.36 | 2482352.9 | 4174513.4 | 43.11 |
| Total | 23 | | | | | | | |
| Cv% | | 2.0 | 9.63 | 10.21 | 5.0 | 15.34 | 9.95 | 13.52 |

**, * and ns, indicated significant at 0.01 and 0.05 probability levels and not significant, respectively.

Table 3: Mean comparisons of maize characteristics in main effects drought stress and micronutrient sprays

| Treatments | | Plant height (cm) | Number of grain per row | Number of grain per ear | 1000 grain weight (gr) | Grain yield (kg ha ⁻¹) | Biological yield (kg ha ⁻¹) | Harvest index (%) |
|----------------------|---------|---------------------|-------------------------|-------------------------|------------------------|------------------------------------|---|--------------------|
| Status of irrigation | Normal | 198.25 ^a | 37.12 ^a | 547.38 ^a | 220.01 ^a | 12099.9 ^a | 24002.1 ^a | 50.57 ^a |
| | Stress | 164.74 ^b | 27.34 ^b | 393.78 ^b | 213.25 ^a | 8441.1 ^b | 17047.7 ^b | 49.27 ^a |
| Micronutrient spray | Control | 170.0 ^d | 27.5 ^b | 393.2 ^b | 212.5 ^a | 8405.8 ^c | 17249 ^b | 48.16 ^a |
| | Fe | 182.5 ^b | 34.1 ^a | 505.5 ^a | 218.0 ^a | 11076 ^{ab} | 22233 ^a | 50.25 ^a |
| | Mo | 177.3 ^c | 30.1 ^b | 431.7 ^b | 216 ^a | 9388.7 ^{bc} | 19434 ^b | 48.51 ^a |
| | Fe + Mo | 199.0 ^a | 37.1 ^a | 551.8 ^a | 220 ^a | 12211.5 ^a | 23183 ^a | 52.76 ^a |

Data with the same letters are not significantly different according to LSD (0.05) probability levels.

Table 4: Response of maize plants height to drought stress and micronutrient sprays interaction

| Micronutrient spray | Control | Fe | Mo | Fe + Mo |
|----------------------|-------------------|------------------|------------------|------------------|
| Status of irrigation | Normal | Stress | Normal | Stress |
| Plant height (cm) | 192 ^{bc} | 150 ^e | 197 ^b | 170 ^d |
| | 194 ^{bc} | 163 ^f | 212 ^a | 186 ^c |

Data with the same letters are not significantly different according to LSD (0.05) probability levels.

Drought induced many complex physiological mechanisms result in oxidative damage due to the overproduction of ROS (Smirnov, 1993). Drought is a multidimensional stress, affecting plants at various levels of their organization (Yordanov et al. 2000). Stress-imposed effects are often manifested at phenological, morpho-physiological, biochemical, and molecular levels (Bahrani et al. 2010).

Biological yield

Growth of cell is severely sensitive to water limitation. Drought stress affected biological yield of maize at 1% probability level (table 2). According to mean comparison, the highest reduction rate was related to water shortage treatment (17047 kg ha⁻¹), in contrast the highest positive effects on biological yield was obtain when Fe and Mo were jointly used as spray treatment (23183 kg ha⁻¹). water stress effects at the vegetative growth stage on biological yield have also been reported by other authors (NeSmith and Ritchie, 1992; Salvador and Pearce, 1995), and could be explained by a decline in plant extension growth, delayed leaf tip emergence and limited leaf size (the photosynthetic factory). Jama and Ottman (1993) have studied the effect of water stress during growth stages, including anthesis, and found that delay in the first irrigation reduces dry matter accumulation rate at all growth stages up to milk stage. Significant rates of dry weight loss due to water deficit in soil during the following stages, probably appeared as a consequence of reduced leaf area increase and stem internode elongation, delayed ear and ovule development, decreased number of kernels due to poor pollination, as well as reduced starch accumulation in the endosperm.

Micronutrients deficiency may either be primary symptoms in plants developments, due to their low total contents in soil factors that limited their availability to plants (Sharma and Chaudhary, 2007). Deficiencies of various micronutrients are related to soil types, crops and even to various cultivars. Most micronutrients, for example Fe is readily fixed in soil having alkaline pH. Plant roots are unable to absorb these nutrients adequately from the dry topsoil (Graham et al., 1992; Foth and Ellis, 1996). Meanwhile, molybdenum as a trace element is essential for chemical changes associated with nitrogen nutrition in plants. In non-legumes (such as wheat, sunflowers and maize), molybdenum enhance the plants performance to take up nitrate by several transporters from the soil and use it. Where the plant has insufficient molybdenum the nitrates accumulate in the leaves and the plant cannot use them to make proteins (Williams and Frausto da Silva, 2002).

Conclusions

As a result of this study it could be concluded that vegetative growth properties (plant height and biological yield) and also reproductive parameters were strongly affected by water stress. In contrast the micronutrient spray such as Iron and Molybdenum could play a key role to elimination or at least alleviation the detrimental effects of drought stress in maize production at the same condition with our study. In fact, their essential role in plant nutrition makes their importance ever greater. To summarize, when plants are not supplied with an optimum amount of Fe and Mo due to many limiting factors such as water stress, growth inhibition and physiological changes

will be appear more quickly, depending on the strength and duration of the imposed stress. Between studied parameters the plant height and biological yield during vegetative growth stage were more sensitive to water limitation due to high reduction. In our study condition the number of grain per row showed more sensitivity to drought stress and well response to micronutrient spray. However the 100 grain weight was much more stable than the other yield components.

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