Response of Maize to Nutrients Foliar Application Under Water Deficit Stress Conditions

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Abstract: Problem statement: To investigate the effect of nutrient application on agronomical characteristic and water use efficiency under water deficit stress of hybrid maize 704, an experiment was arranged in a split plot factorial based on a complete randomized block design with four replicates in the research station of Islamic Azad University-Arak Branch, Iran in 2007. Approach: Main factors studied were four irrigation levels including irrigation equal to crop water requirement, water deficit stress at eight-leaf stage (V8), stage of blister (R2) and stage of filling grain in the main plot. Combined levels of selenium treatment (without and with application 20 g ha⁻¹) were applied 2 weeks before execution of water stress treatment and micronutrients (without and with application) that was provided by specific fertilizer for maize called "Biomin", which contained Fe, Zn, Cu, Mn, B, Mo and Mg in the form of foliar application at six-leaf stage and 1 week before tasseling stage at the rate of 2 L ha⁻¹ were situated in sub plots. Results: Results indicated that effect of water deficit stress on 1000 grain weight, grain yield, harvest index and water use efficiency at different growth stages was significant at 1% level. Water deficit stress decreased grain yield 33% in grain filling stage as compared with control. Using selenium increased mentioned traits but the increase was non significant. Effects of twofold interactions of water deficit stress and selenium showed that using selenium in water deficit stress condition increased measured traits as compared with treatment without selenium. A negative antagonistic interaction was found between selenium and micronutrients on some measured traits. In between treatments of water deficit stress, highest grain yield (8159.33 kg ha⁻¹) was obtained from combined treatment of water deficit stress at eight-leaf stage with selenium application and without micronutrients which compared with treatment of irrigation equal to crop water requirement, without selenium and microelements did not differ significant. Conclusion: According to the results of experiment, using microelements in optimum water availability and using selenium in water deficit stress condition increased mentioned traits as compared to treatments control.

Key words: water deficit, selenium, water use efficiency, grain yield

INTRODUCTION

Maize as a C₄ plant, uptakes a large amount of nutrients from soil during its growth period. In many Asian countries (e.g., Iran) due to the calcareous nature of the soils, high pH, low Organic Matter (OM), salty soil, continuous drought, high bicarbonates in the irrigation water and an imbalanced application of fertilizers, plants growth most of the time affected by different abiotic limitations. Across the globe today, maize (Zea mays L.) is a direct staple food for millions of individuals and, through indirect consumption as a feed crop, is an essential component of global food security. Drought and its consequent stress are one of the important factors which restrict agriculture production in Iran and reduce the use efficiency of dry lands. Therefore recognition and utilization crops tolerant to drought and the special crops improvement methods make it possible to use semi arid region.

Significant yield losses occur due to water stress in both temperate and tropical environments of other continents that also provide maize for local and global
Selenium (Se) is a trace element with some effect may lead to a reduced HI even if water stress around the globe plaguing drought-prone maize production regions is seen as a long-term solution to many of the problems development and adoption of drought-tolerant varieties for their growth insufficient new (concurrent) photosynthates available appear to be weak sinks and will fail if there are strong reduction in total crop dry matter accumulation, if a brief period of stress coincides with the critical index (HI, The fraction of crop dry matter allocated to the grain). This can occur even in the absence of a strong reduction in total crop dry matter accumulation, if a brief period of stress coincides with the critical developmental stage around silking. Developing ovaries appear to be weak sinks and will fail if there are insufficient new (concurrent) photosynthates available for their growth. Alternatively water stress may prevent ovary fertilization by reducing silk receptivity, or low kernel at ear potential may cause kernel growth to cease prematurely. This latter effect may lead to a reduced HI even if water stress occurs late in the grain filling stage.

Selenium (Se) is a trace element with some important functions in living organisms, in particular in animals. Although its role in the animal organism is known in detail, further investigation is required to elucidate its role in plants. It is known that selenium occurs as selenate, selenite, selenide, elemental Se and organic selenium in the soil and that the uptake of selenium by plants is governed by many soil and plant factors. One of the most important factors determining the uptake of this element is the form and concentration of selenium in the soil. Selenium affects metal distribution and sometimes increases the excretion of toxic elements. In some plant species drought stimulates oxidation process which causes accumulation of poisonous oxygen such as free oxygen radical, Hydrogen peroxide and hydroxyl radicals. Variety of active oxygen forms which are produced through stress can damage such cellular constituents as, lipids, carbohydrates, proteins and nucleic acids. Oxidative stress can prevent photosynthetic activity, respiration process and plant growth. Plants are naturally provided by enzymatic and non-enzymatic systems to take care active oxygen.

It is commonly accepted that macro- and microelements play significant roles in plant cells. The interactions between the elements in the soil and in plant organisms are very important and well known.

Iron (Fe) enters many plant enzymes that play dominant roles in oxidoredox reactions of photosynthesis and respiration. Iron participates in content of many enzymes: Cytocchromes, ferredoxine, Superoxide Dismutase (SOD), Catalase (CAT), peroxidase and nitrate reductase. The deficiency of Fe in plants causes significant changes in the plant metabolism and induces chlorosis, especially in young leaves and leads to very low re-utilization.

Manganese (Mn), in turn, is regarded as an activator of many different enzymatic reactions and takes part in photosynthesis. Manganese activates decarboxylase and dehydrogenase and is a constituent of complex PSII-protein, SOD and phosphatase. Deficiency of Mn induces inhibition of growth, chlorosis and necrosis, early leaf fall and low re-utilization.

Copper (Cu) is an essential micronutrient for plant metabolism, acts as a component of several enzymes and is involved in carbohydrates, N and cell wall metabolism. It is constituent of plastocyanine, cytochrome oxidase, tyrosinase, SOD and nitrate reductase. Deficiency of Cu induces chlorosis of leaves.

Zinc (Zn) is an essential trace element for every living organism. About 200 enzymes and transcription factors require Zn as a functional component. This element plays an important role in protein and carbohydrate synthesis and takes part in metabolism regulation of saccharides, nucleic acid and lipid metabolism. One of the first symptoms of Zn deficiency is an inhibition of cell growth and proliferation. Zinc affects growth of shoots and roots and growth symptoms of Zn toxicity in plants, generally, are similar to those of Zn deficiency. The toxic concentrations of Zn negatively affect photosynthetic electron transport and photophosphorylation and have an effect on the photosynthetic enzymes.
One of the primary mechanisms of Zn toxicity may be an increased permeability of root membranes, which will cause nutrients to leak out from the roots[18]. Application of microelements fertilizers can enhance plants resistance to environmental stresses such as drought and salinity[7].

In this study, the effect of the selenite ion and microelements on some agrophysiological characteristics of maize has been studied under water deficit stress conditions.

**MATERIALS AND METHODS**

In order to study the effect of water deficit stress and nutrient elements application on kernel number per ear, 1000 kernel weight, grain yield, harvest index and water use efficiency in maize (KSC 704), a field experiment was carried out in the Research Station of Islamic Azad University, Arak Branch, Iran in 2007. The experimental design was split plot factorial based on complete randomized block design with four replications. Four irrigation levels including, without water stress (control), water deficit stress in Vegetative stage (V), water deficit stress in blister stage (R) and water deficit stress in grain filling stage (R) were assigned to main plot and combination of 20 g ha⁻¹ Se (without and with using sodium selenite-NaHSeO₃) and microelements without and with using specific fertilizer for maize called "Biomin" which contained Fe, Zn, Cu, Mn, B, Mo and Mg in the form of foliar application at six-leaf stage and one week before tasseling stage at the rate of 2 lit ha⁻¹ were situated in sub plots that randomized to sub-plots. Soil preparation including ploughing was done in fall and perpendicular disks in May 2007. Each plot constituted seeded liners distanced 75 cm from each other and 20 cm distance between each two plants on the lines. The length of each seeded line was six meters and two furrows between each two plots were unseeded. Lines were hand-seeded on 18th of May 2007. One third of nitrogen and all of phosphorous fertilizers on the basis of soil analysis applied at sowing time and the remaining nitrogen fertilizer at two different periods during plant growth stages. Before sowing, combined soil samples to a 0-30 and 30-60 cm depth were collected and their physical and chemical properties were tested. Specifically, our test included determination pH using the hydrometry method[12] and of a saturated paste[29], organic C (wet oxidation method)[26], total N (Kjeldahl method)[25] and the concentration of available P (sodium bicarbonate extraction method)[27], available K(flame photometer method, emission spectrophotometry)[19], Fe and Mn (Diethylenetriaminepentaacetic Acid (DTPA), using atomic absorption spectrometer, Model Perkin Elmer 3110) were determined (Table 1). Final harvest was performed at physiological maturity stage when a black layer was formed at seed base.

At maturity stage, grain yield was determined from a harvest area of 1.5×4 m (2 rows middle of each experimental plot) and expressed on a 15% moisture basis. To determine water use efficiency the following relation was applied:

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\text{Water use economic efficiency} = \frac{\text{Grain yield (kg ha}^{-1}\text{)/water used (m}^3\text{ ha}^{-1}\text{)}}
\]

Mean comparison was conducted using Duncan’s multiple range test[31].

**RESULTS AND DISCUSSION**

Effects of water deficit stress on 1000 grain weight, grain yield, harvest index and water use efficiency at different growth stages was significant at 1% level. Mean comparison of treatments indicate that highest rate of 1000 grain weight, grain yield, harvest index and water use efficiency related to treatment of without water deficit stress and the lowest grain yield, harvest index and water use efficiency belonged to plants under water deficit stress in grain filling stage (Table 2). Water deficit stress decreased grain yield 12.75% in stage Vₕ, 16.3% in stage of blister and 33% in stage of grain filling as compared with control. In seed filling period, reducing growth period irregularities in transfer of photosynthetic materials caused by water deficit, will effect on seed weights as one of the yield components. Decrease in grain yield can due to reduced leaf, silk and grain kernel expansion, reduced assimilate flux to growing organs, accelerated leaf senescence, delayed silk growth and greater ear and kernel abortion[23]. Also result of this research is parallel with results of other researchers[2,3,21,30].

Effect of selenium on grain yield, harvest index and water use efficiency was not significant, but with using selenium mentioned traits, were increased.
Application of selenium increased grain yield 2.1% in compared with control (Table 2). This is important from viewpoint of quantity and quality for consumption human and animals.

Application of microelements decreased kernel number per ear and grain yield significantly at 5% level, but on 1000 grain weight, harvest index and water use efficiency was not significant. This may be related to antagonistic interaction of microelements to each other. In maize, with copper application alone and along with iron and manganese decreased kernel number per ear, 1000 grain weight and grain yield[17].

Results of two fold interactions water deficit stress and selenium on grain yield, harvest index and water use efficiency was significant. Highest seed yield was obtained from control treatment (Without stress and without Selenium) which showed significant differences in compared to other treatments. Using selenium in water deficit stress condition increased mentioned traits as compared to treatment without using selenium. In between treatments of stress, the highest magnitude of measured traits was found from treatment of water deficit stress in stage V8. Least grain yield under water deficit was obtained from treatment of water deficit stress in grain filling stage and without Selenium application (Table 3). This might be indicative of plant sensitivity due to no protection factor under water stress. Using microelements in water optimum conditions increased traits measured as compared to without microelements but in water deficit stress conditions in all growth stages, all of traits were decreased. Presumable in water deficit stress condition due to increasing of concentration these elements in plant toxicity created.

### Table 2: Mean comparison of main and interaction effects of characters on Kernel Number per ear (KNE), 1000 grain weight (1000 GW), Grain Yield (GY), Harvest Index (HI) and Water Use Efficiency (WUE)

| Treatment       | KNE | 1000 gw (g) | GY (kg ha⁻¹) | HI (%) | WUE (kg m⁻²) |
|-----------------|-----|-------------|--------------|--------|--------------|
| Water limitation|     |             |              |        |              |
| L₁              | 503.26a | 199.66a | 8024.87a | 53.39a | 0.95a        |
| L₂              | 403.62b | 194.66a | 6989.19b | 48.51b | 0.97a        |
| L₃              | 438.44ab | 174.97b | 6712.08b | 47.94b | 0.93a        |
| L₄              | 471.92ab | 142.66c | 5385.73c | 44.59b | 0.75b        |
| Selenium:       |     |             |              |        |              |
| Se₀             | 448.39a | 175.97a | 6703.49a | 48.50a | 0.88a        |
| Se₁             | 460.22a | 180.00a | 6852.45a | 48.73a | 0.91a        |
| Microelement:   |     |             |              |        |              |
| M₀              | 466.61a | 178.26a | 6938.41a | 48.66a | 0.92a        |
| M₁              | 442.01b | 177.70a | 6617.53b | 48.56a | 0.87a        |

Mean followed by the same letters in each column are not significantly (Duncan multiple rang test 5%): L₁: Optimum condition; M₀: Without microelement; L₂: Water limitation in V8 stages; M₁: With microelement; L₃: Water limitation in blister stages; Se₀: Without selenium; L₄: Water limitation in dough stages; Se₁: With selenium

### Table 3: Mean comparison of two fold interaction effects of characters on Kernel Number per Ear (KNE), 1000 Grain Weight (1000 GW), Grain Yield (GY), Harvest Index (HI) and Water Use Efficiency (WUE)

| Treatment       | KNE | 1000 kw (g) | GY (kg ha⁻¹) | HI (%) | WUE (kg m⁻²) |
|-----------------|-----|-------------|--------------|--------|--------------|
| Water limitation|     |             |              |        |              |
| Water limitation|     |             |              |        |              |
| L₁              | 516.75a | 206.16a | 9143.88a | 55.09a | 1.08a        |
| Se₀             | 489.77a | 183.19b | 6904.86bc | 51.70ab | 0.82c        |
| Se₁             | 411.51b | 200.62ab | 7360.72b | 49.83bc | 1.02a        |
| M₀              | 439.30b | 166.98cd | 6594.80c | 49.83bc | 0.91b        |
| M₁              | 437.59b | 182.96bc | 6829.35bc | 49.32bc | 0.94b        |
| Selenium:       |     |             |              |        |              |
| Se₀             | 444.24b | 132.04e | 4457.60d | 42.39d | 0.62d        |
| Se₁             | 499.59a | 153.29d | 631n3.87c | 46.79cd | 0.87b        |
| Water limitation|     |             |              |        |              |
| Water limitation|     |             |              |        |              |
| L₁              | 505.13a | 178.97bc | 7841.27a | 52.31ab | 0.93ab       |
| M₀              | 501.38a | 210.31a | 8208.47a | 54.47a | 0.97ab       |
| M₁              | 418.62b | 204.69a | 7152.66b | 47.72bc | 0.99a        |
| L₂              | 418.62b | 204.69a | 7152.66b | 47.72bc | 0.99a        |
| M₀              | 388.62b | 194.66a | 6825.72bc | 49.31bc | 0.95ab       |
| M₁              | 393.28c | 198.70ab | 6617.66c | 47.19bc | 0.92b        |
| L₃              | 476.58b | 182.14bc | 6994.74bc | 47.40c | 0.97ab       |
| M₀              | 403.31b | 182.14bc | 6429.41c | 48.49bc | 0.89b        |
| M₁              | 403.31b | 182.14bc | 6429.41c | 48.49bc | 0.89b        |
| L₄              | 466.09a | 147.25a | 5764.96d | 47.72c | 0.80c        |
| M₀              | 477.44a | 138.07d | 5006.51e | 41.96d | 0.70b        |
| M₁              | 446.86a | 132.04e | 4457.60d | 42.39d | 0.62d        |

Mean followed by the same letters in each column are not significantly (Duncan multiple rang test 5%): L₁: Optimum condition; M₀: Without microelement; L₂: Water limitation in V8 stages; M₁: With microelement; L₃: Water limitation in blister stages; Se₀: Without selenium; L₄: Water limitation in dough stages; Se₁: With selenium
A negative antagonistic interaction was found between selenium and microelements in traits of kernel number per ear, grain yield and water use efficiency but 1000 grain weight and harvest index were increased with using both selenium and microelements not significantly (Table 3). Decrease in amount of these traits may be due to antagonistic interaction between microelements and selenium.

Three fold interactions experimental factors had significant effect on grain yield and water use efficiency.

The highest amounts of 1000 grain weight (212.56 g), grain yield (9519.05 kg ha⁻¹), harvest index (56.03%) and water use efficiency (1.11 kg m⁻²) obtain from treatment of water optimum condition + without selenium + with microelements (Table 4). Using selenium and microelements alone in water deficit stress conditions in vegetative growth stage and dough stage increased grain yield, water use efficiency in compared to without using this elements in water stress conditions (Table 4). Presumably in the end of growth period that increased stress conditions, selenium and microelements with take part in biological activity of cells, induced health protection and permanent in function of membranes. In general, it is concluded that by using selenium and microelements under water stress can yield better as compared to without using this elements. Microelements take part in protein synthesis, metabolism regulation of saccharides, nucleic acid and lipid metabolism. Enters the oxidoredoctase enzymes, acts as a component of several enzymes: Superoxide Dismutase (SOD), catalase, peroxidase and nitrate reductase and cytochromes, ferredoxine. Therefore when plants are deficient of these elements, activities of antioxidant enzymes decrease imposing and increased sensitivity to environmental stresses.

**CONCLUSION**

Long-term trends in global climate change and the expansion of maize production into marginal areas are generating a greater number of drought-prone maize production environments across the globe. Increases in global temperatures as a result of rising greenhouse gas concentrations could potentially accelerate maize growth and development, hasten maturity and reduce soil moisture. Improvements in maize drought tolerance are therefore vital for maintaining local and global food security. In general, plants tolerated unfavorable environmental conditions by changing their morphology as living indices. Selenium as necessary trace element for living organisms is an essential component for activity of antioxidant enzymes system. With using selenium traits of grain yield, harvest index and water use efficiency increased. Use of selenium in water deficit stress condition increased grain yield, harvest index and water use efficiency significantly. Other microelements such as Fe, Zn, Cu, Mg and Mn also play their role as cofactors in the structure of many antioxidant enzymes, therefore when plants are deficient of these elements activities of antioxidant enzymes decrease imposing increased sensitivity to environmental stresses. Using microelements in water optimum condition increased traits measured as

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Table 4: Mean comparison of threefold interaction effects of characters on Kernel Number per Ear (KNE), 1000 Grain Weight (1000 GW), Grain Yield (GY), Harvest Index (HI) and Water Use Efficiency (WUE)

| Treatment | KNE (per ear) | 1000 kw (g) | GY (kg ha⁻¹) | HI (%) | WUE (kg m⁻²) |
|-----------|---------------|-------------|--------------|-------|--------------|
| L₁        | M₀ Se₀      | 526.40a     | 199.74abc    | 8768.72ab | 54.15ab | 1.03ab     |
| L₁        | M₀ Se₁      | 507.10ab    | 212.56a      | 9519.05a  | 56.03a  | 1.11a      |
| L₁        | M₀ Se₂      | 468.77abc   | 185.19efg    | 6913.83cde | 50.47abcdef | 0.82ef   |
| L₁        | M₀ Se₃      | 468.77abc   | 208.06ab     | 6897.90cde | 52.92abc | 0.82f      |
| L₁        | M₀ M₀ M₀   | 391.14f     | 201.53abc    | 6146.00def | 46.42def | 0.86def    |
| L₁        | M₀ M₀ M₀   | 395.43ef    | 195.88abc    | 7089.33cde | 47.97bcde | 0.99bc     |
| L₁        | M₀ M₀ M₀   | 446.10bcdef | 207.85ab     | 8159.33b  | 49.02abcde | 1.13a     |
| L₁        | M₀ M₀ M₀   | 381.80f     | 193.39abcd   | 6562.11cdef | 50.65abcde | 0.91cdef  |
| L₁        | M₀ M₀ M₀   | 489.23abc   | 175.85cde    | 7242.94a  | 51.08abcd | 1.00bc     |
| L₁        | M₀ M₀ M₀   | 389.37f     | 158.12efg    | 5946.66ef | 47.56bcde | 0.82ef     |
| L₁        | M₀ M₀ M₀   | 463.93abcd  | 188.44abcd   | 6746.55cdef | 43.72edef | 0.93bced   |
| L₁        | M₀ M₀ M₀   | 411.25def   | 177.47bcde   | 6912.16cde | 49.41abcde | 0.96bcde   |
| L₁        | M₀ M₀ M₀   | 431.73cdf   | 129.70g      | 4711.77g  | 44.34def | 0.65g      |
| L₁        | M₀ M₀ M₀   | 456.76bcdef | 134.38g     | 4202.44g  | 40.44f  | 0.61g      |
| L₁        | M₀ M₀ M₀   | 500.46abc   | 164.80abcdef | 6818.16cde | 50.09abcde | 0.94bcde   |
| L₁        | M₀ M₀ M₀   | 498.73ab    | 141.77f      | 5809.58f  | 43.49ef  | 0.80f      |
| L₁        | M₀ M₀ M₀   | 507.10ab    | 212.56a      | 9519.05a  | 56.03a  | 1.11a      |
| L₁        | M₀ M₀ M₀   | 526.40a     | 199.74abc    | 8768.72ab | 54.15ab | 1.03ab     |

Mean followed by the same letters in each column are not significantly (Duncan multiple rang test 5%) %: L₁: Optimum condition: M₀: Without microelement; L₂: Water limitation in V₈ stages; M₀: With microelement; L₃: Water limitation in blister stages; Se₀: Without selenium; L₄: Water limitation in dough stages; Se₃: With selenium.
compared to without microelements but in water deficit stress condition in all growth stages traits were decreased. Using of selenium and microelements in water deficit stress condition in vegetative growth stage and dough stage increased yield, water use efficiency as compared to without using this elements in water stress condition.

The combined results of these studies indicate that by using selenium and microelements under water stress can produce stable yield as compared to without using this elements.

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