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ORIGINAL PAPER

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FOLIAR APPLICATION OF TECAMIN MAX® TO ALLEVIATE WATER DEFICIT EFFECTS ON YIELD AND WATER-USE EFFICIENCY (WUE) OF OKRA

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ABSTRACT

This study was designed to observe the effects of different rates of foliar application of Tecamin max® on growth, yield and water use efficiency (WUE) of okra under water deficit. The field experiment was conducted from April till July 2016 at the teaching and research farm of University of Diyala, Iraq. Performance of okra genotype 'Samara' and 'Ptira' was assessed by foliar application of Tecamin max® at (0, 2.5 and 5.0 mL L^{-1}) and two irrigation levels (50 and 100% based on field capacity). The results showed that chlorophyll content, fruit weight, yield per plant, total yield and WUE were significantly affected by genotype and irrigations levels and application of Tecamin max®. 'Samara' genotype had the highest chlorophyll content, fruit weight, yield per plant, total yield and water use efficiency. Foliar application of Tecamin max® at the rates of 2.5 mL L^{-1} showed the highest fruit weight, yield performance and WUE. It was followed by foliar application of 5.0 mL L^{-1}. No application of Tecamin max® showed the worst results in all the studied traits.

Key words: *Abelmoschus esculentus*, amino acids, chlorophyll, foliar spray, plant yield, water use efficiency, water stress

INTRODUCTION

Okra or lady finger (*Abelmoschus esculentus* (L.) Moench) is grown mainly for its pods that are used fresh, canned, dried or ground as powder. It is rich in pectin, vitamins, fiber and calcium, magnesium and potassium. Okra mucilage is used as a plasma replacement or blood volume expander. Seeds of okra are a potential source of oil with concentrations varying from 20 to 40%, mostly consisting linoleic acid, a polyunsaturated fatty acid essential for human nutrition. Okra is a powerhouse of valuable nutrients, nearly half of which is soluble fiber in the form of gums and pectin, which helps to lower serum cholesterol, reducing the risk of heart diseases. Okra is also abundant in several carbohydrates, minerals and vitamins, that play a vital role in human diet and health [Mihretu et al. 2014, Gemede et al. 2014]. High yield and quality of okra depends on improved genotypes in combination with good agricultural practices.

Population growth leads to increased water consumption and lower per capita share due to increasing social and industrial water needs as well as climate change and deterioration in the quantity and quality of water, which may cause a decline in agricultural land. Water stress is one of the most serious factors affecting

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the growth and productivity of agricultural crops, in addition to the continuous increase in the drought problem resulting from global climate change towards drought, which affects the food stocks [Ahmed 2016]. As agriculture is one of the largest water-consuming areas, considerable efforts are being made to rationalize water consumption by improving water management in agricultural systems [UNEP 2006]. Despite many decades of research, drought continues to be a major challenge due to its unpredictable occurrence, timing, severity and duration. Drought tolerant crops with consistent yield under extensive periods of mild or severe stress are essential for sustaining global food production. Hence, it will be useful to introduce to breeding programs the genotypes identified as adaptive in the target areas [Naveed et al. 2012].

In recent years, many studies were devoted to the ways to reduce water consumption in the agricultural sector, including the use of certain natural and chemical products that are added to the soil or plant to reduce evaporation and drought damage. Among these products, Tecamin max® – the amino acid – is the main factor in protein formation. It is important to note that it plays an important role in the continuation of metabolism during drought, controls the state of closing and opening of the stomata and reduces evaporation and transpiration from leaves and increased plant content of chlorophyll. Understanding the mechanism of drought impact on plant growth and productivity can overcome functional symptoms of plants in the harsh environments of thirst, drought or water deficit. Water soluble fertilizers are applied to foliage to boost nutrient availability to plants. They improve the efficiency of soil-applied nutrients, act as a catalyst in the uptake and use of certain micronutrients [Ayub et al. 2018], which increases both yield and crop quality [Abd El-Aal et al. 2010, Abbasi et al. 2010]. The aim of the study was to determine effects of a water soluble, foliar applied fertilizer in reducing the negative impact of water deficit on okra.

MATERIALS AND METHODS

Experimental design and soil analysis

The experiment was carried out in vegetable fields, the Department of Horticulture and Landscape Gardening, College of Agriculture, University of Diyala, Iraq. The soil was well drained silty loam. The chemical properties of the soil were $CaCO_3$ (260.10 g kg^{-1}), EC1:1 (7.55 dS m^{-1}), organic matter (OM) (6.90 g kg^{-1}), nitrogen (N), phosphorous (P) and potassium (K) as 54.01, 8.04 and 81.79 mg kg^{-1}, respectively. Bulk density was 1.35 Mmg m^{-3}. Field capacity (FC) = 25%. The irrigation water was EC-water = 0.83 ds m^{-1}. Soil analyses was done according to processes detailed by Black [1965] and Jackson [1958]. The experimental design was arranged in a split-split plot, in a randomized complete block design with three factors: the first – two genotypes ('Ptira' and 'Samara'), the second – two levels of irrigation (50 and 100% of field capacity), the third – three levels of Tecamin max® (0, 2.5 and 5.0 ml L^{-1}). Seeds were planted on 5th April 2016, with four seeds per hill. The adopted spacing was 1 m between rows and 0.5 m between plants, with 12 plants per experimental unit and the number of plants was 25,000 plants per hectare. Resulting in 12 treatments, replicated in three blocks, totaling 36 plots. The nutrient composition of the Tecamin max® is shown in Table 1. The Tecamin max® were sprayed three times every 10 days from the beginning of flowering. A backpack sprayer was used to spray the nutrient solution or water. All foliar spraying was carried out early in the morning using backpack sprayer. The trial was kept relatively weed-free almost every week till harvest. Plant protection and agronomic practices were carried out during crop growth.

Table 1. Nutrient composition of foliar fertilizer TM

Analysis (wt/vol.)		
Total amino acids	TAA	14.4%
L-amino acids	L-AA	12%
Total nitrogen	N	7%
Organic matter	OM	60%
pH		6.6

Data measurement

6 plants were randomly selected from each plot for data recording and observation and observations

were recorded upon: chlorophyll content in leaves (SPAD), leaf chlorophyll concentration was measured by optical readings at SPAD-502 meter (Konica Minolta, Japan). Six independent SPAD measurements were made per plot, using different plants, fruit weight (g), plant yield (g), total yield (t ha^{-1}) and the WUE (kg m^{-3}) of drip and furrow irrigation system was calculated by the formula:

$$\text{WUE (kg m}^{-3}\text{)} = Y/WY$$

where:
Y – yield (dry matter) of crop (kg ha^{-1}),
WR – total water consumed for crop production (m^3 ha^{-1}).

The plants were harvested every two days when the fruits showed intense green color, for 86 days with a total of 14 harvests.

Statistical analysis

Data were analyzed by one-way ANOVA with the Tukey's multiple range tests to separate means using SAS 9.1 statistical software. In all cases, differences were deemed to be significant if $P < 0.05$.

RESULTS AND DISCUSSION

Results in Table 2 explain that there was a difference between genotype in all the studied traits. 'Samara' plants had recorded the highest mean value of chlorophyll content in leaves (56.05 SPAD), fruit weight (9.43 g), more yield per plant (420.05 g), total yield (10.501 t ha^{-1}) and WUE (20.890 kg m^{-3}). Whereas 'Ptira' plants produced lower chlorophyll content in leaves with mean value of 51.27 SPAD, fruit weight (7.63 g) yield per plant (287.55 g), total yield 7.188 t ha^{-1} and WUE with mean value 13.583 kg m^{-3} (Tab. 2). The reason for this can be attributed to genetic differences between genotypes or that this variation might be due to the involvement of environment factors and genotypic effect in the quantitative and qualitative traits of the plant. Understanding the genetic variability and response of these okra genotypes to drought stress will facilitate planning and execution of okra genetic improvement programs in Iraq [Hamdi 2017, Ali 2017, Souza Medeiros et al. [2018]. Such breeding programs can be geared towards development of resilient okra genotype, which can help cushion the negative effects of climate

Table 2. Effects of genotypes, irrigation levels and Tecamin max® on chlorophyll content in leaves, fruit weight, yield per plant, total yield and WUE in okra

Factors	Chlorophyll (SPAD)	Fruit weight (g)	Plant yield (g)	Total yield (t ha^{-1})	WUE (kg m^{-3})
Genotypes					
'Ptira'	51.27b	7.63b	287.55b	7.188b	13.583b
'Samara'	56.05a	9.43a	420.05a	10.501a	20.890a
Irrigation (%)					
50	51.50b	8.26b	342.66b	8.599b	21.965a
100	55.83a	8.81a	364.94a	9.123a	12.507b
Tecamin max® (mL L^{-1})					
0	54.25c	7.88c	289.50c	7.237c	13.709c
2.5	56.91b	9.13a	394.66a	9.866a	19.874a
5.0	58.83a	8.59b	377.25b	9.431b	18.126b

Data in interaction analyzed with Least Squares Means and means separated with Tukey
Values in groups in columns followed by the same letter are not significantly different, $P < 0.05$

Table 3. Effect of 3-way interaction between genotypes × irrigation levels × Tecamin max® foliar application on chlorophyll content in leaves, fruit weight, yield per plant, total yield and WUE

Genotypes	Irrigation levels (%)	Tecamin max (ml L^{-1})	Chlorophyll (SPAD)	Fruit weight (g)	Plant yield (g)	Total yield (t ha^{-1})	WUE (kg m^{-3})
'Ptira'	50	0	41.66i	6.70h	224.00d	5.60d	41.66i
		2.5	52.00fg	8.16defg	294.67c	7.36c	52.00fg
		5.0	54.00ef	7.38fgh	299.00c	7.47c	54.00ef
	100	0	46.00h	7.10gh	252.67d	6.31d	43.66hi
		2.5	56.00de	8.39def	348.33b	8.70b	56.00de
		5.0	58.00cd	8.06efg	306.67c	7.66c	58.00cd
'Samara'	50	0	43.66hi	8.66cde	329.00bc	8.22bc	46.00h
		2.5	58.00cd	9.49abc	455.00a	11.37a	58.00cd
		5.0	59.66bc	9.16bcd	454.33a	11.35a	59.66bc
	100	0	49.66g	9.06bcde	353.33b	8.80b	49.66g
		2.5	61.66ab	10.47a	480.67a	12.01a	61.66ab
		5.0	63.66a	9.76ab	449.00a	11.22a	63.66a

Data in interaction analyzed with Least Squares Means and means separated with Tukey's test
Values in columns followed by the same letter are not significantly different, $P < 0.05$

change on poor resourced okra farmers [Singh et al. 2018]. The variation might be due to their diverse genetic makeup and high photosynthetic efficiency of some cultivars as compared to other cultivars, which affects the fruit weight and yield [Naheed et al. 2013, Sam-Amoah et al. 2016]. Also, plants irrigated at 100% maximum of chlorophyll content in leaves (55.83 SPAD value), fruit weight (8.81 g), yield per plant (364.94 g) and total yield (9.123 t ha^{-1}), while plants irrigated at 50% had the lowest produced chlorophyll content in leaves with mean value 51.50 SPAD, fruit weight (8.26 g), plant yield (342.66 g), less the total yield (8.599 t ha^{-1}). This is attributed to availability of water for the physiological functions of the plants and full irrigation provides a consistent supply of water to the entire root area on a continuous basis, which reduces "drench and dry-out" stresses [Barzegar et al. 2016, Hamdi 2017]. Water deficit stress is a major abiotic factor affecting the crop yield. Plants are known to have developed different physiological and biochemical mechanisms to overcome the effects and impacts of water deficit stress [Farias et al. 2017, Shivaraj et al. 2018]. Most morphological, physiological and biochemical processes associated with plant development are obstructed during water deficit stress, resulting in poor photosynthesis, respiration and nutrient metabolism. Plants respond to and mitigate the adverse effects of drought using one or a combination of the following mechanisms: earliness or escape, drought avoidance, drought tolerance and drought recovery [Deveci et al. 2017]. Water deficit stress causes an important decrease in the photosynthetic rate in both genotypes of plants [Barzegar et al. 2016].

The 50% irrigation treatment produced the maximum WUE (21.965 kg m^{-3}), whereas the 100% irrigation treatment had the lowest WUE (12.507 kg m^{-3}). There was a decrease in WUE as irrigation level increased. This was attributed to increased applied water. Over-irrigation has been reported to result in lower water productivity, while a lack of irrigation caused very low water productivity. Plants treated with 5.0 ml l^{-1} Tecamin max® had the highest content of chlorophyll in leaves (58.83 SPAD value), compared with other treatment. Plants treated with 2.5 and 5.0 ml l^{-1} Tecamin max® produced the highest fruit weight (9.13 g), yield per plant (394.66 g), total yield (98.66 t ha^{-1}) and WUE (19.874 kg m^{-3}), compared with control treatment, which produced the lowest values 7.88 g, 289.50 g, 7.237 t ha^{-1} and 13.709 kg m^{-3}, respectively. Positive responses to Tecamin max® may be because it increased efficiency of photosynthesis, improved growth, compensated for loss of nutrients due to water deficit, increased flowers set ratio, reduced negative effects of water deficit, and improved fruit quality. Tecamin max® contains amino acids, nitrogen, phosphorus, potassium, and seaweed extract (Tab. 1), its use may compensate the deficiency of elements by root uptake due to water deficit [Abo El-Hamd and Abd Elwahed 2018]. Variation in responses might be due to the role of Tecamin max® in uptake of nitrogen, sulfur or phosphorous and cell elongation properties or to genetic makeup of cultivars [Siddiqui et al. 2008, Akinyele and Osekita 2011, Barzegar et al. 2016, Souza Medeiros et al. 2018]. Application of foliar Tecamin max® increases the uptake of calcium, which plays a major role in the mitotic cell division of apical meristems [Souza Medeiros et al. 2018]. This growth enhancement might be due to stimulation of growth by improving the nutrient efficiency or indirectly by their effect on the cation exchange capacity of plants [Siddiqui et al. 2008, Barzegar et al. 2016].

Results in Table 3 show that more fruit weight, yield plant and total yield were produced on 'Samara', with complete irrigation, and due to treatment with both levels of Tecamin max®, with 2.5 ml l^{-1} producing more than 5.0 ml l^{-1} Tecamin max®. 'Samara' irrigated at 100% produced the highest chlorophyll content in leaves and WUE was greater with 100% irrigation and treatment with both levels of Tecamin max®.

CONCLUSIONS

Foliar spraying application with Tecamin max® significantly increased all the studied traits regardless of the genotype and irrigation level.

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