



## TECAMIN FLOWER® FOLIAR APPLICATION TO ALLEVIATE WATER DEFICIT EFFECTS ON GROWTH, YIELD AND WATER USE EFFICIENCY OF TOMATO

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**ABSTRACT.** During drought chemical elements in a dry fertilizer go into solution in the soil with difficulty and the nutrients are less available to the plant. Foliar fertilization with Tecamin flower®, could compensate for nutrient deficiency due to water deficit. This study was designed to observe the effects of different application rates of foliar application of Tecamin flower® on growth, yield and field water use efficiency (CWUE) of tomato under water deficit. The field experiment was conducted from March till July 2016 at the teaching and research farm of Diyala University, Iraq. Performance of tomato genotype 'Bobcat', 'Finenss' and 'Hadeer' was assessed by foliar application of Tecamin flower® at (0 and 2.5 mL L<sup>-1</sup>) 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 CWUE were significantly affected by genotype and irrigations levels and application of Tecamin flower®. 'Bobcat' genotype has the highest value of plant yield (3.39 kg) and total yield (90.19 t ha<sup>-1</sup>). 'Finenss' has the highest values for number fruit per plant (40.75), CWUE (75.37 kg m<sup>-3</sup>) and the minimum leaf proline content (2.584 mg g<sup>-1</sup>). Plant irrigated at 100% had the highest value of number fruit (35.27 fruit), most yield per plant (3.53 kg), total yield (94.02 t ha<sup>-1</sup>) and minimum leaf proline content (2.557 mg g<sup>-1</sup>). The highest CWUE (84.50 kg m<sup>-3</sup>) were at 50% level. Plant treated at 2.5 mL L<sup>-1</sup> Tecamin flower® had most fruit/plant (37.61) yield per plant (3.73 kg), total yield (99.16 t ha<sup>-1</sup>), CWUE (85.22 kg m<sup>-3</sup>) and minimum leaf proline content (2.437 mg g<sup>-1</sup>).

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### Introduction

Tomato (*Solanum lycopersicum* L. from the Solanaceae family) is an important, popular and nutritious vegetable all over the world. It plays a vital role in providing a substantial quantity of vitamins C, A and lycopene in human diet, and is also an effective antioxidant exhibiting high quenching ability for singlet oxygen. Considerable evidence from several epidemiological research suggested that lycopene has anti-carcinogenic and anti-atherogenic potential (Juarez-Maldonado *et al.*, 2016; Klunklin *et al.*, 2017; Bruno *et al.*, 2018; Martí *et al.*, 2018).

High yield and quality of tomato and drought tolerance, diseases depend on improved genotypes in combination with good agricultural practices. The selection

of a good genotype is a prerequisite for the success of the agricultural process. Differences in the broad genotypes among tomato varieties have enabled this crop to spread in a variety of environments. Genetic variation between tomato genotypes enable this crop to be grown in diverse environments. There is a growing deficit of available water that could lead to loss of arable cropland. To breed drought-tolerant cultivars, it is necessary to identify physiological and morphological characters that produce a high, stable, yield under deficit soil moisture (White 2011; Shah *et al.*, 2015; Buhroy *et al.*, 2017; Hamdi, 2017 Al-Shammari *et al.*, 2018a).

With increasing population, urbanization and industrialization, competition for water is increasing worldwide. Population increase requires additional food. Domestic water supplies, consumer goods, and water

for environmental compete for existing water resources. Worldwide, more than 40% of food production depends on irrigation water (Ahmad, 2016). Since agriculture is the major consumer of freshwater resources, efforts towards improving water use efficiency will be worthwhile. Drought certainly is one of the most effective factors of the environmental problems that has a great bad effect on the agricultural production, and greatly affecting crop growth, yield quantity, the variety and the quality of the essential physiological and biochemical processes in plants. Exposing plants to drought has an effect on the plant-water relations and decreases the water content in the leaves and whole the plant leading to osmotic stress. It is usual that plants suffer from the environmental stress. Decrease in the water content conditions causes a reduction in the plant photosynthetic efficiency and stomatal conductance which inhibits Rubisco activity and breaks down energy balance and breaks down the distribution during photosynthesis. The world populations expanding demands food from more crops but with less water (IWMI; Giuliani *et al.*, 2011; Patane *et al.*, 2011; Ahmad, 2016).

Also, the foliar nutrition for plant such as the Spraying of Nutrient Solution (Tecamin flower<sup>®</sup>) have a great effect on improving drought tolerance in tomato plants. Water soluble fertilizers are applied to foliage to boost nutrient availability to plants. It improves the efficiency of soil-applied nutrients and acts as a catalyst in the uptake and use of certain macronutrients, and increases crop yield and quality (Al-Shammari *et al.*, 2018b; Al-Shammari *et al.*, 2018c; Al-Shammari *et al.*, 2018d). The aim of study was to determine effects of a water-soluble, foliar applied, fertilizer in reducing the negative impact of water deficit on tomato genotypes.

### Materials and Methods

An experiment was carried out in the vegetable fields, Department of Horticulture and Landscape Gardening, College of Agricultural, University of Diyala, Baqubah, Iraq, located 70 km north of Baghdad, to study effects of Tecamin flower<sup>®</sup> and water deficit on growth, yield and water use efficiency of tomato.

The soil was a well-drained silty loam with chemical properties of CaCO<sub>3</sub> (260.10 g kg<sup>-1</sup>), EC<sub>1:1</sub> (7.55 Ds m<sup>-1</sup>), organic matter (OM) (6.90 g kg<sup>-1</sup>), and nitrogen (N), phosphorous (P) and potassium (K) as 54.01, 8.04 and 81.79 mg kg<sup>-1</sup>, respectively. Bulk density was 1.35 g cm<sup>-3</sup>. Field capacity (FC) 25%. The irrigation water had EC<sub>1:1</sub> of 0.83 dS m<sup>-1</sup>. Soil analyses was done according to processes of Black *et al.* (1965) and Jackson (1958). Poultry manure was added at 3 kg m<sup>-2</sup>. Distance between rows was 1.25 m and 0.30 m between plants to produce a density of 26,666 plants ha<sup>-1</sup>. The experimental plot length was 3 m with an area of 3.75 m<sup>2</sup> and each experimental unit contained 13 plants. Seed of tomato cvs. 'Bobcat', 'Finenss' and

'Hadeer' were planted on 25 January 2016 in cork trays, of 0.50 × 1 m with 209 holes per tray, containing peat moss medium. The soil was irrigated and brought to field capacity 2 days before seedlings were transplanted. When seedlings reached the 3–5 true leaf stage they were established by hand in the field on 5 March 2016. The experiment continued until 1 July 2016. For surface drip irrigation T-Tape with emitters of 11 cm a distance, 4 L h<sup>-1</sup> flow rate and 16 mm diameter were used. Fertilization and other cultural practices were applied as recommended in commercial tomato production (Maynard, Hochmuth, 2007).

The experiment was arranged in a split-split plot design within a completely random distribution. The experiment included the factors tomato cvs. 'Bobcat', 'Finenss' and 'Hadeer' as main plots; 50 or 100% irrigation based on field capacity as the first split-plot and 0 or 2.5 mL L<sup>-1</sup> of Tecamin flower<sup>®</sup> as the sub-subplot, there were 12 treatments, replicated in 5 blocks, totalling 60 plots. Tecamin flower<sup>®</sup>, which contains important nutrients (Table 1), was applied with a backpack sprayer 4 times at a 10-day interval beginning at flowering.

**Table 1.** Nutrient composition of foliar fertilizer (Tecamin flower<sup>®</sup>)

Material	Amount (wt/vol.), %
Boron (B)	1
Seaweed extract	4
L-amino acids	3
Nitrogen (N)	3
Phosphorus (P <sub>2</sub> O <sub>5</sub> )	10
Molybdenum (Mo)	0.5

Tomato plants were treated until run-off with the nutrient solution or water, with application carried out in early morning. Sampling estimated moisture content before each irrigation and according to the weight method and soil depth of 0–30 cm to the flowering stage and 0–60 cm to the end of the growing season. Full irrigation water amount was calculated using the equation of Allen *et al.* (1998).

Data were subjected to analysis of variance in SAS (ver. 9.1, SAS, Inc., Cary, NC). If interactions were significant they were used to explain results. If interactions were not significant means were separated using Tukey's test.

Eight plants were randomly selected from each plot to determine the following Characteristics: Proline concentration was determined using ninhydrin colourimetric methods of Bates *et al.* (1973). Fruits number, plant yield, total yield (t ha<sup>-1</sup>) and field water use efficiency of drip and furrow irrigation systems was calculated by the formula:

$$CWUE \text{ (kg m}^{-3}\text{)} = Y/WR$$

$$CWUE = \text{Field water use efficiency.}$$

$$\text{where } Y = \text{Yield of plants (kg ha}^{-1}\text{)}$$

$$WR = \text{Total water requirement (m}^3 \text{ ha}^{-1}\text{)}$$

Harvest was performed manually on June 15, 2016.

### Results

Data in Table 2 depicts that genotype 'Bobcat' produced the maximum yield per plant, total yield as compared to rest of the genotypes. While 'Finenss' produced the highest number fruit, CWUE and the minimum leaf proline content than all other tomato genotypes.

Plant irrigated at 100% level had the largest number fruit per plant, yield per plant, total yield and minimum leaf proline content, compared with other treatment. While Plant irrigated at 50% level produced the highest CWUE, compared to 100% irrigated plants, which produced less CWUE (Table 2).

Plant treated at 2.5 mL L<sup>-1</sup> Tecamin flower® had least leaf proline content, most fruit number, plant yield, total yield and CWUE, compared to the control treatment, which gave the lowest values (Table 2).

For the genotype by irrigation rate the responses for leaf proline content, fruit number, yield per plant, total yield and CWUE varied (Table 3). 'Finenss' irrigated at 100% level had the minimum leaf proline content, and most fruit number, compared with other treatment. The same genotype irrigated at 50% produced the highest CWUE, in contrast, Hadeer had consistently lower CWUE at 100% irrigation. While 'Bobcat' irrigated at 100% level produced the highest yield per plant, total yield, compared with other treatment.

The genotypes by Tecamin flower® rate interaction affected in all studied traits (Table 3). 'Finenss' treated at 2.5 mL L<sup>-1</sup> Tecamin flower® had least leaf proline content, most fruit number, plant yield, total yield and CWUE, compared with other treatment.

For the irrigation rate by Tecamin flower® rate the values for in all studied traits varied (Table 3). Plant irrigated at 100% level treated with the 2.5 mL L<sup>-1</sup> Tecamin flower® rate had least leaf proline content, most fruit number, plant yield and total yield, compared with other treatment. The highest CWUE was for plants treated with 2.5 mL L<sup>-1</sup> Tecamin flower® rate irrigated at 50%, compared with other treatment.

Data in Table 4 show the genotype and irrigation-level with Tecamin flower® rate interaction affected on the leaf proline content, fruit number, yield per plant, total yield and field Water use efficiency of tomato. 'Finenss' irrigated at 100% level treated with 2.5 mL L<sup>-1</sup> Tecamin flower® rate had the minimum leaf proline content and most fruit number, compared with other treatment. The highest CWUE was for the 2.5 mL L<sup>-1</sup> Tecamin flower® rate under 50% irrigation were recorded for the same tomato genotypes, compared with other treatment. While 'Bobcat' irrigated at 100% level with treated 2.5 mL L<sup>-1</sup> Tecamin flower® rate produced the highest yield per plant and total yield, compared with other treatment.

**Table 2.** Effects of genotypes, irrigation levels and Tecamin flower® application on the leaf proline content, fruit number, yield per plant, total yield and field water use efficiency of tomato

Genotypes	Proline, mg g <sup>-1</sup>	Fruits per plant	Plant yield, kg	Total yield, t ha <sup>-1</sup>	CWUE, kg m <sup>-3</sup>
'Bobcat'	2.987 <sup>a</sup>	26.00 <sup>c</sup>	3.39 <sup>a</sup>	90.19 <sup>a</sup>	57.91 <sup>a</sup>
'Finenss'	2.584 <sup>c</sup>	40.75 <sup>a</sup>	3.14 <sup>a</sup>	83.72 <sup>a</sup>	75.37 <sup>a</sup>
'Hadeer'	2.617 <sup>b</sup>	31.91 <sup>b</sup>	2.75 <sup>b</sup>	73.13 <sup>b</sup>	61.38 <sup>b</sup>
Irrigation levels (%)					
50	2.901 <sup>a</sup>	30.50 <sup>b</sup>	2.65 <sup>b</sup>	70.67 <sup>b</sup>	84.50 <sup>a</sup>
100	2.557 <sup>b</sup>	35.27 <sup>a</sup>	3.53 <sup>a</sup>	94.02 <sup>a</sup>	57.27 <sup>b</sup>
Tecamin max® (mL L <sup>-1</sup> )					
0	3.021 <sup>a</sup>	28.16 <sup>b</sup>	2.46 <sup>b</sup>	65.53 <sup>b</sup>	56.55 <sup>b</sup>
2.5	2.437 <sup>b</sup>	37.61 <sup>a</sup>	3.73 <sup>a</sup>	99.16 <sup>a</sup>	85.22 <sup>a</sup>

Data in interaction analyzed with Least Squares Means and means separated with Tukey.

<sup>a, b, c</sup> values in groups in columns followed by the same letter are not significantly different, P<0.05.

**Table 3.** Interaction effect of genotypes and irrigation, genotypes and Tecamin flower® irrigation levels and Tecamin flower® on the leaf proline content, fruit number, yield per plant, total yield and field water use efficiency of tomato

Genotypes ×	Irrigation, %	Prolin, mg g <sup>-1</sup>	Fruits per plant	Plant yield, kg	Total yield, t ha <sup>-1</sup>	CWUE, kg m <sup>-3</sup>
'Bobcat'	50	3.242 <sup>a</sup>	28.00 <sup>b</sup>	2.61 <sup>cd</sup>	69.56 <sup>cd</sup>	84.40 <sup>b</sup>
	100	2.731 <sup>c</sup>	24.00 <sup>c</sup>	4.17 <sup>a</sup>	110.78 <sup>a</sup>	67.42 <sup>c</sup>
'Finenss'	50	2.721 <sup>d</sup>	38.00 <sup>b</sup>	3.04 <sup>bc</sup>	80.88 <sup>bc</sup>	97.89 <sup>a</sup>
	100	2.448 <sup>f</sup>	43.50 <sup>a</sup>	3.25 <sup>b</sup>	86.56 <sup>b</sup>	52.84 <sup>d</sup>
'Hadeer'	50	2.741 <sup>b</sup>	34.33 <sup>c</sup>	3.31 <sup>d</sup>	61.54 <sup>d</sup>	71.21 <sup>c</sup>
	100	2.492 <sup>e</sup>	29.50 <sup>d</sup>	3.19 <sup>b</sup>	84.73 <sup>b</sup>	51.54 <sup>d</sup>
Genotypes × Tecamin flower®, mL L <sup>-1</sup>						
'Bobcat'	0	3.408 <sup>a</sup>	21.50 <sup>e</sup>	2.61 <sup>c</sup>	69.37 <sup>c</sup>	58.99 <sup>b</sup>
	2.5	2.566 <sup>d</sup>	30.50 <sup>c</sup>	4.18 <sup>a</sup>	111.01 <sup>a</sup>	92.84 <sup>a</sup>
'Finenss'	0	2.848 <sup>b</sup>	37.00 <sup>b</sup>	2.19 <sup>d</sup>	58.31 <sup>d</sup>	52.17 <sup>c</sup>
	2.5	2.321 <sup>f</sup>	44.50 <sup>a</sup>	4.10 <sup>a</sup>	109.13 <sup>a</sup>	98.56 <sup>a</sup>
'Hadeer'	0	2.808 <sup>c</sup>	26.00 <sup>d</sup>	2.59 <sup>c</sup>	68.93 <sup>c</sup>	58.50 <sup>b</sup>
	2.5	2.425 <sup>e</sup>	37.83 <sup>b</sup>	2.90 <sup>b</sup>	77.34 <sup>b</sup>	64.25 <sup>b</sup>
Irrigation (%) × Tecamin max®, mL L <sup>-1</sup>						
50	0	3.316 <sup>a</sup>	35.33 <sup>b</sup>	2.06 <sup>d</sup>	54.84 <sup>d</sup>	66.71 <sup>b</sup>
	2.5	2.486 <sup>c</sup>	30.66 <sup>c</sup>	3.25 <sup>b</sup>	86.50 <sup>b</sup>	102.2 <sup>a</sup>
100	0	2.726 <sup>b</sup>	25.66 <sup>d</sup>	2.86 <sup>c</sup>	76.23 <sup>c</sup>	46.39 <sup>c</sup>
	2.5	2.388 <sup>d</sup>	39.88 <sup>a</sup>	4.20 <sup>a</sup>	111.82 <sup>a</sup>	68.15 <sup>b</sup>

Data in the interaction analyzed with Least Squares Means and means separated using Least Significant differences.

<sup>a, b, c, d</sup> values in the column followed by the same letter are not significantly different, P<0.05.

**Table 4.** Effect of 3-way interaction between genotype×irrigation level×Tecamin flower® foliar application on leaf proline content, fruit weight, plant yield, total yield and field water use efficiency (CWUE) in tomato fruit

Genotypes	Irrigation levels, %	Tecamin flower, ml L <sup>-1</sup>	Proline, mg g <sup>-1</sup>	Fruits per plant	Plant yield, kg	Total yield, t ha <sup>-1</sup>	CWUE, kg m <sup>-3</sup>
'Bobcat'		0	3.850 <sup>a</sup>	19.00 <sup>h</sup>	2.07 <sup>e</sup>	55.17 <sup>e</sup>	67.11 <sup>de</sup>
	50	2.5	2.635 <sup>e</sup>	29.00 <sup>f</sup>	3.16 <sup>c</sup>	84.02 <sup>c</sup>	101.70 <sup>b</sup>
	100	0	2.966 <sup>d</sup>	24.00 <sup>g</sup>	3.14 <sup>c</sup>	83.57 <sup>c</sup>	50.86 <sup>f</sup>
'Finess'		2.5	2.497 <sup>h</sup>	32.00 <sup>e</sup>	5.20 <sup>a</sup>	138.00 <sup>a</sup>	83.98 <sup>c</sup>
	50	0	3.101 <sup>b</sup>	35.00 <sup>d</sup>	2.06 <sup>e</sup>	54.90 <sup>e</sup>	66.79 <sup>de</sup>
	100	2.5	2.341 <sup>i</sup>	41.00 <sup>b</sup>	4.02 <sup>b</sup>	106.86 <sup>b</sup>	129.00 <sup>a</sup>
'Hadeer'		0	2.595 <sup>g</sup>	39.00 <sup>c</sup>	2.32 <sup>de</sup>	61.72 <sup>de</sup>	73.56 <sup>g</sup>
	50	2.5	2.301 <sup>j</sup>	48.00 <sup>a</sup>	4.18 <sup>b</sup>	111.40 <sup>b</sup>	68.13 <sup>de</sup>
	100	0	2.998 <sup>c</sup>	23.00 <sup>g</sup>	2.04 <sup>e</sup>	54.46 <sup>e</sup>	66.25 <sup>e</sup>
'Hadeer'		2.5	3.850 <sup>a</sup>	19.00 <sup>h</sup>	2.07 <sup>e</sup>	55.17 <sup>e</sup>	67.11 <sup>de</sup>
	50	0	2.635 <sup>e</sup>	29.00 <sup>f</sup>	3.16 <sup>c</sup>	84.02 <sup>c</sup>	101.70 <sup>b</sup>
	100	2.5	2.966 <sup>d</sup>	24.00 <sup>g</sup>	3.14 <sup>c</sup>	83.57 <sup>c</sup>	50.86 <sup>f</sup>

Data in the interaction analyzed with Least Squares Means and means separated using Least Significant differences.

<sup>a, b, c, d</sup> values in the column followed by the same letter are not significantly different, P<0.05.

## Discussion

Difference in genotype for some traits are due to their ability to absorb nutrients from the soil or through leaves better than others (Hamdi, 2017) the reason for this can be attributed to genetic differences between genotypes. (Bhattarai *et al.*, 2016; Al-Shammari *et al.*, 2018a).

The full irrigation promoted the growth of tomato plants by increasing fruit number, plant yield, total yield and least leaf proline content, according to our opinion, they attributed this 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 so that "drench and dry-out" stresses are reduced. Reduction in water supply during the growth and development of tomato tends to lead to overall yield. Most morphological, physiological and biochemical processes associated with plant development are obstructed during water deficit stress thus resulting in poor photosynthesis, respiration, and nutrient metabolism (Giuliani *et al.*, 2016; Cantore *et al.*, 2016; Ya-dan, 2017; Zhang *et al.*, 2018).

Previously published research on fruit yield produced results which are similar to the data obtained in this study. Similarly, Hamdi (2017) found that full irrigation resulted in maximum fruit number, yield per plant, total yield and least leaf proline content. According to a study conducted by Al-Shammari *et al.* (2018a), the total yield increases in relation to the amount of water applied. Besides, Ya-dan (2017) determined that a negative trend in response to increasing soil water deficit was observed for fruit yield.

When the applied water is reduced, it affects physiological processes and exposes plants to drought transmission to different parts of the plant (Wang, Xing, 2017). An efficient use of limited water resources and better growth under limited water supply are desirable traits for crops grown under drought-prone environments. Plants respond to and mitigate the adverse effects of drought using any, or a combination, of the following mechanisms: earliness or escape, drought avoidance, drought tolerance and drought recovery (Yuan *et al.*, 2016; Hamdi, 2017).

Foliar application of Tecamin flower® played a role in alleviating negative impact of water deficit, and improved plant growth, yield and CWUE, positive responses to Tecamin flower® may be because it increased the efficiency of photosynthesis, improved growth, compensated for the loss of nutrients due to water deficit, increased flowers set ratio, reduced negative effects of water deficit, and improved fruit quality. Tecamin flower® contains amino acids, nitrogen, phosphorus, potassium, and seaweed extract, and its use may compensate the deficiency of elements by root uptake due to water deficit (Spann, Little 2010; Pane *et al.*, 2013; Boteva, 2016; Camen *et al.*, 2016; Sidhu, Nandwani, 2017 Al-Shammari *et al.*, 2018b; Al-Shammari *et al.*, 2018c). Application of foliar Tecamin flower® increases uptake of calcium which plays a major role in the mitotic cell division of apical meristems.

## Conclusions

The wide variation in all the genotypes might be due to their genetic makeup, which indirectly govern the morphology of the plant that have direct impact on formation of floral, Increase the weight and number of fruits. Foliar application of Tecamin flower® played a role in alleviating negative impact of water deficit, and improved plant growth, yield and CWUE.

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## Conflict of interest

The authors declare that they have no conflict of interest.

## Author contributions

GH 50%, AA 25%, MAH 25% – study conception and design;  
GH 100% – acquisition of data;  
GH 100% – analysis and interpretation of data;  
GH 100% – drafting of the manuscript.  
GH 100% – critical revision and approve the final manuscript.

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