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# Improvement in Production, Fruit Quality and Water Use Efficiency of Three Tomato Cultivars by Foliar Application of Tecamin Flower® Under Water Deficit Conditions

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## ABSTRACT

During drought, chemical elements in a fertilizer go into solution in the soil with difficulty and nutrients are less available to plants. Foliar fertilization with water soluble Tecamin flower®, a product containing chemicals needed by plants, compensates for nutrient deficiency by roots due to water deficit. The study was undertaken to evaluate impacts of foliar application of Tecamin flower® at 0 or 2.5 ml/l and deficit irrigation (50 or 100% of field capacity) in tomato (*Solanum lycopersicum* L.) cvs. Bobcat, Finenss and Hadeer. The results showed that 'Bobcat' cultivar produced the highest vitamin C content, fruit firmness and total yield. 'Finenss' had the highest total soluble solids and water use efficiency (WUE). 'Hadeer' had the highest titratable acidity and the lowest pH. Plants irrigated at a 50% rate produced the highest vitamin C content, total soluble solids, fruit firmness and the lowest pH. 100% irrigation resulted with the highest yield and WUE. The plant treated with 2.5 ml/l Tecamin flower® produced the highest vitamin C content, total soluble solids, titratable acidity, fruit firmness, total yield, WUE and the lowest pH. Foliar application of Tecamin flower®, regardless of cultivar, improved production, fruit quality and WUE of tomato under normal and water deficit conditions and played a role in alleviating the negative impact of water deficit.

**Keywords:** amino acids, genotype, *Solanum lycopersicum*, water levels

## INTRODUCTION

Tomato (*Solanum lycopersicum* L.) fruits are rich in carbohydrates, vitamins, organic acids, mineral salts and fiber (Sozzi and Fraschinal, 1997; Sesso et al., 2003; Gerszberg and Hnatuszko-Konka, 2017; Xu et al., 2018). and it can be grown in various agricultural environments with high production. (Hamdi, 2017). The chemical composition of tomato fruit varies with cultivar, weather conditions, soil, agricultural processes and water deficit. Productivity of tomato is affected by drought, especially during flower set.

Water shortage is the most important determinant of tomato production in arid and semi-arid regions (Gilbert and Medina, 2016; Giuliani et al., 2018; Al-Shammari et al., 2018a). It is necessary to study factors affecting water availability to achieve rational water use, especially in irrigation of agricultural crops (Farooq et al., 2012; Ahmad, 2016; Brillante et al., 2016).

Tecamin flower® nutrient solutions contribute to increasing tolerance of plants to biotic and abiotic stresses (Al-Shammari et al., 2018b). Foliar application of nutrient solutions may overcome the negative effects of water shortage.

This is done by compensating for lack of nutrient uptake in plants due to drought by applying solutions rich in amino acids and elements necessary for plant growth and formation of a balanced plant habit.

Use of drought resistant varieties, and addition of boron, molybdenum, nitrogen, phosphorus, seaweed extracts and free amino acids to plants or soil, are used to improve plant tolerance to drought (Osakabe et al., 2014; Daryanto et al., 2017; Luoa and Li, 2018; Al-Shammari et al., 2019; Abood et al., 2019). These chemicals regulate plant nitrogen osmotic condition, maintain metabolism during dehydration, control the state of stomata, minimize evaporation by transpiration, stimulate biological processes, divide cells, form cell walls, increase chlorophyll, increase absorption of positive ions, promote flowering, prevent flower abortion due to drought, and improve fruit quality (Ragab et al., 2015; Luoa and Li, 2018). Therefore, this study was initiated to evaluate the effectiveness of the foliar application of Tecamin flower® in reducing the negative impact of water deficit and whether it can improve tomato production and quality.

## MATERIALS AND METHODS

The study was carried out at the Department of Horticulture and Landscape Gardening, Faculty of Agriculture, University of Diyala, Baqubah, Iraq. Seed of tomato cvs. Bobcat, Finenss, and Hadeer were planted on 25 Jan. 2018 in cork trays, 0.50 × 1 m, with 209 holes per tray, containing peat moss as a medium, in an unheated glasshouse (temperature: 30.7±2.8 °C max, 11.1±3.1 °C min; relative humidity (%): 71.8±4.1 min to 90.5±1.9 max,) and without any supplemental lighting during seedling growth.

Irrigation, fertilizer, and pesticide application were as described by Hamdi (2017). When seedlings reached the 3-5 true leaf stage they were transplanted to the open field.

The soil was a well-drained silty loam containing $CaCO_3$ (260.10 g/kg), $EC_{1:1}$ (7.55 dS/m), organic matter (OM) (6.90 g/kg), and nitrogen (N), phosphorous (P) and potassium (K) as 54.01, 8.04 and 81.79 mg/kg, respectively. The soil was prepared by ploughing to a 30-cm depth with a single pass of a tractor-mounted moldboard plow. Bulk density was 1.35 g/cm$^3$ while field capacity (F.C) was 25%. The irrigation water had $EC_{1:1}$ of 0.83 dS/m. Soil analyses was according to Black et al. (1965) and Jackson (1958).

Poultry litter was added at 3 kg/m$^2$ during bed preparation. The large amount of litter was used because high temperatures in the summer, average 46°C, for 6 months, leads to quick oxidation of organic matter. Distance between rows was 1.25 m and 0.30 m between plants to produce a density of 26.666 plants/ha.

The soil was irrigated and brought to field capacity 2 days before the seedlings were transplanted on 5 Mar 2018. The experiment continued until 1 July 2018, Irrigation was initiated when 50% of water-holding capacity was consumed (Faberio et al., 2002) in a 30 cm soil depth to bring the measured soil moisture content in FC. Full irrigation water amount was calculated using the equation of Allen et al. (1998).

Experimental plot length was 3 m with an area of 3.75 m$^2$ and each experimental unit contained 13 plants. For surface drip irrigation (T-Tape®, Rain-Flo Irrigation, East Earl, PA), 16 mm in diameter with emitters 11 cm apart and a 4 l/h flow rate was used. Fertilization and other cultural practices were applied as recommended in commercial tomato production (Maynard and Hochmuth, 2007).

The experimental design was arranged in a split-split plot, in a randomized complete block design, with 3 factors. The first factor was cultivars three of tomato (Bobcat, Finenss, and Hadeer) were distributed in main plots. The second factor was level of irrigation, 50 or 100% based on field capacity (F.C) were distributed in sub-plots. The third factor was level of Tecamin flower® at 0 or 2.5 mg/l were distributed in sub-sub plots. There were 12 treatments, replicated in three blocks, totaling 36 plots. Tecamin flower® supplies various nutrients used by plants (Table 1).

**Table 1.** Nutrient composition of foliar applied Tecamin flower® fertilizer

| Material | Amount (wt: vol.) |
|---|---|
| Boron (B) | 1% |
| Seaweed extract | 4% |
| L-amino acids | 3% |
| Nitrogen (N) | 3% |
| Phosphorus ($P_2O_5$) | 10% |
| Molybdenum (Mo) | 0.5% |

Data were collected from 6 randomly selected plants from each plot. Ascorbic acid (vitamin C) was measured by the 2, 6-dichloroindophenol titrimetric method (Anonymous, 1984). Total soluble solids (TSS) of tomato juice were determined with a handheld refractometer (PR-32, Co. Ltd., Tokyo, Japan) with automatic temperature compensation. Titratable acidity was measured with 0.1 mol/l NaOH and calculated as equivalents of citric acid expressed as percent of fresh mass. Fruit firmness was detected using a fruit firmness tester (FHR-5, Takemura Electric Works, Ltd., Tokyo, Japan) on the fruit shoulder 1.5 cm from blossom scar using a cylindrical probe (5 mm dia). The pH of tomato juice was measured using a pH meter (CH-8603, Mettler-Toledo GmbH, Schwerzenbach, Switzerland) Total yield t/ha and values of water use efficiency (kg/$m^3$) were calculated for different treatments after harvest according to the following equation:

*Water use efficiency (WUE) =Total yield / Water applied* (1)

***Statistical analysis***

At harvest, 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 tests.

## RESULTS AND DISCUSSION

Results in Table 2 showed the effect of cultivars on all measured traits. 'Bobcat' had the highest vitamin C content, fruit firmness and total yield, while the 'Fineness' cultivar had the least. 'Finenss' had the highest total soluble solids, while the 'Hadeer' cultivar had the least. The highest WUE was produced on 'Bobcat' and 'Finenss'. 'Hadeer' had the highest titratable acidity and the lowest pH, compared with other cultivars. The difference in cultivar for some traits are due to their ability to absorb nutrients from the soil or through leaves better than others, which is exhibited in production, fruit quality and WUE, the reason for this can be attributed to genetic differences between genotypes (Hamdi, 2017; Xu et al., 2018).

For the irrigation rate the responses for all measured traits (Table 2). Plants treated with 100% irrigation level had the highest vitamin C content, total soluble solids, titratable acidity, fruit firmness and the lowest pH. The highest total yield and WUE were produced with irrigated plants at 50% level. The highest vitamin C content, total soluble solids, titratable acidity, fruit firmness, total yield, WUE and lowest of pH was produced at plant treated with 2.5 ml/l Tecamin flower® (Table 2). Reducing irrigation improved fruit quality (Vitamin C, titratable acidity, total soluble solids, fruit firmness, pH) and WUE and increased dry matter content (Savic et al., 2011; Hamdi, 2017; Haile, 2018). Reductions in water accumulation resulted in decreased water content per fruit and increased soluble solids and vitamin C content, titratable acidity, fruit firmness and pH. Some fruit quality characteristics of tomato could be enhanced by decreasing application of water (Al-Harbi et al., 2017; Luoa and Li, 2018), the tomato fruit is the strongest sink for assimilates among plant organs, when the plants were irrigated with less water, the plant would adjust the osmotic level in sink organs to increase sucrose and organic acids transformation rate and amount, and increase the sucrose gradient between leaves and fruit. Consequently, more assimilates were transported to the fruit and improved total soluble solids, titratable acidity, fruit firmness and pH, but reduced water transportation into fruit. Over-irrigation has been reported to result in lower water productivity, while a lack of irrigation caused very low water productivity (Hamdi, 2017).

**Table 2.** Impacts of cultivars, irrigation levels and Tecamin flower® application on vitamin C (V.C), total soluble solids (TSS), titratable acidity (TA), pH, fruit firmness (F.F), total yield (T.Y) and water use efficiency (WUE) in tomato

| Factors | V.C mg/100 ml | TSS % | TA % | pH | F.F kg/cm² | T.Y t/ha | WUE kg/m³ |
|---|---|---|---|---|---|---|---|
| Cultivars | | | | | | | |
| Bobcat | 16.66[a] | 5.45[b] | 0.74[b] | 4.51[b] | 7.17[a] | 89.39[a] | 73.78[a] |
| Finenss | 15.32[c] | 5.55[a] | 0.70[c] | 4.55[a] | 5.50[c] | 82.50[b] | 73.80[a] |
| Hadeer | 16.32[b] | 5.30[c] | 0.76[a] | 4.41[c] | 5.74[b] | 72.26[c] | 60.42[b] |
| Irrigation levels % | | | | | | | |
| 50 | 17.34[a] | 5.86[a] | 0.79[a] | 4.39[b] | 6.58[a] | 69.19[b] | 56.34[b] |
| 100 | 14.96[b] | 5.01[b] | 0.69[b] | 4.64[a] | 5.69[b] | 93.58[a] | 82.33[a] |
| Tecamin flower® ml/l | | | | | | | |
| 0 | 15.10[b] | 5.23[b] | 0.69[b] | 4.54[a] | 5.86[b] | 63.84[b] | 54.00[b] |
| 2.5 | 17.21[a] | 5.63[a] | 0.78[a] | 4.46[b] | 6.42[a] | 98.93[a] | 84.66[a] |

Values in the column followed by the same letter are not significantly different

The plant which was treated with 2.5 ml/l Tecamin flower® had the highest vitamin C content, total soluble solids, titratable acidity, fruit firmness, total yield, WUE and lowest pH, compared with the control treatment (Table 2). Higher fruit quality appears to be due to effects of Tecamin flower®, which improves fruit nutrient content because Tecamin flower® contains seaweed extract, free amino acids, molybdenum, phosphorus, and nitrogen. These nutrients increase fruit quality. Higher fruit quality due to treatment with 2.5 ml/l Tecamin flower® might be due to enhanced of vegetative growth, leading to enhanced accumulation of solids and more conversion of organic acids to sugar, vitamin C, total soluble solids, titratable acidity, fruit firmness and increased nutrient level and might be too increase of nitrogen that found in this product (Tecamin flower®). The general improvement in plant growth, yield and WUE due to application of Tecamin flower® may be due to providing nutrients directly to tissues. Positive effects of application of Tecamin flower® may be due to osmo-regulatory since it is soluble in water and increases concentrations of cellular osmotic components. Amino acids are useful in withstanding adverse environmental conditions because they increase the photosynthesis efficiency, improve growth, compensate for the loss of nutrients due to water deficit, increase flowers set ratio, and reduce negative effects of water deficit (Singh et al., 2017; Al-Shammari et al., 2018b; Al-Shammari et al., 2019; Abood et al., 2019).

The vitamin C content was improved due to use of 2.5 ml/l Tecamin flower® for each cultivar; 'Hadeer' and 'Bobcat' had highest vitamin C content at the 2.5 ml/l Tecamin flower® rate. The highest titratable acidity and fruit firmness was produced on 'Bobcat' with use of Tecamin flower®. The highest total soluble solids, total yield and WUE were produced on 'Finenss' with use of Tecamin flower® followed by cv. 'Bobcat'. For 'Hadeer' cv., use of Tecamin flower® produced the lowest of pH (Table 3).

Reducing irrigation by half, and addition of Tecamin flower®, did not negatively affect most characteristics of cultivars (Table 3). For 'Bobcat' and 'Hadeer' the highest vitamin C content was due to irrigation at the 100% rate, for 'Finenss' the highest vitamin C content was due to irrigation at the 50% rate. The highest overall vitamin C content and lowest pH was for 'Hadeer' at the 50% irrigation rate.

**Table 3.** Means comparison the interaction impacts of cultivars × irrigation levels and cultivars × Tecamin flower® and irrigation levels × Tecamin flower® on vitamin C content (V.C), total soluble solids (TSS), titratable acidity (T.A), pH, fruit firmness (F.F), Total yield (T.Y) and water use efficiency (WUE) in tomato

| Factors | | V.C mg/100 ml | TSS % | TA % | pH | F.F kg/cm² | T.Y t/ha | WUE kg/m³ |
|---|---|---|---|---|---|---|---|---|
| Cultivars | Tecamin flower® ml/l | | | | | | | |
| Bobcat | 0 | 15.50c | 5.13c | 0.63f | 4.58b | 6.80b | 67.62c | 54.73c |
| | 2.5 | 17.83a | 5.67a | 0.83a | 4.49c | 7.55a | 111.17a | 92.83a |
| Finenss | 0 | 14.70d | 5.40b | 0.67e | 4.60a | 5.25f | 56.87d | 50.22c |
| | 2.5 | 16.26b | 5.71a | 0.74d | 4.50c | 5.75d | 108.13a | 97.39a |
| Hadeer | 0 | 15.10cd | 5.16c | 0.75c | 4.44d | 5.53e | 67.03c | 57.07bc |
| | 2.5 | 17.54a | 5.43b | 0.78b | 4.38e | 5.69c | 77.50b | 63.77b |
| Cultivars | Irrigation levels % | | | | | | | |
| Bobcat | 50 | 17.28b | 5.80b | 0.83a | 4.34e | 7.95a | 68.34bc | 66.92c |
| | 100 | 16.05d | 5.10c | 0.65e | 4.73a | 6.40b | 101.45a | 80.64b |
| Finenss | 50 | 14.20f | 5.96a | 0.74c | 4.45d | 5.75d | 79.10bc | 51.65d |
| | 100 | 16.26b | 5.15c | 0.66d | 4.65b | 5.25e | 85.91b | 95.96a |
| Hadeer | 50 | 17.99a | 5.81b | 0.78b | 4.29f | 6.04c | 60.14d | 50.43d |
| | 100 | 14.65e | 4.78b | 0.75c | 4.54c | 5.44e | 84.39bc | 70.38bc |
| Irrigation levels % | Tecamin flower® ml/l | | | | | | | |
| 50 | 0 | 16.01b | 5.63b | 0.71b | 4.39c | 6.36b | 52.55d | 44.88c |
| | 2.5 | 18.68a | 6.08a | 0.86a | 4.33d | 6.79a | 85.83b | 67.79b |
| 100 | 0 | 14.19c | 4.83d | 0.66d | 4.69a | 5.35d | 75.13c | 63.12b |
| | 2.5 | 15.74b | 5.18c | 0.71c | 4.59b | 6.04c | 112.04a | 101.53a |

Data in the interaction analyzed with least Squares Means and means separated with Tukey test

Values in the column followed by the same letter are not significantly different

The highest titratable acidity and fruit firmness were on 'Bobcat' irrigated at 50% and most total yield were on same cultivar at 100% irrigation rate. The highest total soluble solids were on 'Finenss' irrigated at 50% and the highest WUE were on same cultivar at 100% irrigation rate.

For the irrigation by Tecamin flower® interaction values for measured variables varied (Table 3). The highest vitamin C content, total soluble solids, titratable acidity, fruit firmness, most total yield, WUE and lowest pH, was determined for plants treated with the 2.5 ml/l Tecamin flower® for each irrigation level.

For the cultivar by irrigation level by Tecamin flower® rate interaction values for measured variables varied (Table 4). Total soluble solids were generally the highest in each combination for the 2.5 ml/l Tecamin flower® rate regardless of cultivar or irrigation level. The exception was for the 'Hadeer' where values were similar regardless of irrigation level and Tecamin flower® rate. In this interaction titratable acidity for each combination was highest for the 2.5 ml/l Tecamin flower® rate regardless of cultivar or irrigation level. For this interaction pH was

**Table 4.** Means comparison the interaction impacts of cultivars, irrigation levels and Tecamin flower® on vitamin C content (V.C), total soluble solids (TSS), titratable acidity (T.A), pH, fruit firmness (F.F), Total yield (T.Y) and water use efficiency (WUE) in tomato

| Cultivars | Irrigation levels % | Tecamin flower® ml/l | V.C mg/100 ml | TSS % | TA % | pH | F.F kg/cm$^2$ | T.Y t/ha | WUE kg/m$^3$ |
|---|---|---|---|---|---|---|---|---|---|
| Bobcat | 50 | 0 | 15.94$^{ef}$ | 5.40$^{d}$ | 0.67$^{h}$ | 4.38$^{f}$ | 7.60$^{b}$ | 82.57$^{c}$ | 49.50$^{g}$ |
| | | 2.5 | 18.62$^{b}$ | 6.20$^{a}$ | 0.99$^{a}$ | 4.30$^{g}$ | 8.30$^{a}$ | 138.33$^{a}$ | 84.34$^{c}$ |
| | 100 | 0 | 15.06$^{fg}$ | 4.86$^{ef}$ | 0.62$^{j}$ | 4.78$^{a}$ | 6.00$^{de}$ | 52.66$^{ef}$ | 59.96$^{def}$ |
| | | 2.5 | 17.03$^{cd}$ | 5.33$^{d}$ | 0.67$^{h}$ | 4.69$^{b}$ | 6.80$^{c}$ | 84.02$^{c}$ | 101.33$^{b}$ |
| Finenss | 50 | 0 | 15.70$^{ef}$ | 5.80$^{c}$ | 0.71$^{f}$ | 4.50$^{d}$ | 5.60$^{f}$ | 60.42$^{de}$ | 36.18$^{h}$ |
| | | 2.5 | 17.83$^{bc}$ | 6.13$^{ab}$ | 0.78$^{c}$ | 4.40$^{e}$ | 5.90$^{def}$ | 111.40$^{b}$ | 67.12$^{de}$ |
| | 100 | 0 | 13.70$^{i}$ | 5.00$^{e}$ | 0.63$^{i}$ | 4.70$^{b}$ | 4.90$^{g}$ | 53.33$^{ef}$ | 64.26$^{def}$ |
| | | 2.5 | 14.69$^{gh}$ | 5.30$^{d}$ | 0.69$^{g}$ | 4.60$^{c}$ | 5.60$^{f}$ | 104.86$^{b}$ | 127.66$^{a}$ |
| Hadeer | 50 | 0 | 16.41$^{de}$ | 5.70$^{c}$ | 0.76$^{d}$ | 4.29$^{g}$ | 5.90$^{def}$ | 82.39$^{c}$ | 48.97$^{gh}$ |
| | | 2.5 | 19.58$^{a}$ | 5.93$^{bc}$ | 0.79$^{b}$ | 4.28$^{h}$ | 6.19$^{d}$ | 86.39$^{c}$ | 51.93$^{fg}$ |
| | 100 | 0 | 13.80$^{hi}$ | 4.63$^{f}$ | 0.73$^{e}$ | 4.59$^{c}$ | 5.16$^{g}$ | 51.66$^{f}$ | 65.16$^{de}$ |
| | | 2.5 | 15.50$^{fg}$ | 4.93$^{e}$ | 0.76$^{d}$ | 4.49$^{d}$ | 5.73$^{ef}$ | 68.61$^{d}$ | 75.61$^{cd}$ |

Data in the interaction analyzed with least Squares Means and means separated with Tukey test
Values in the column followed by the same letter are not significantly different

always higher for the 0 ml/l Tecamin flower® rate and the 50% irrigation level regardless of cultivar.

For this interaction fruit firmness level was generally highest for the 2.5 ml/l Tecamin flower® rate regardless of cultivar or irrigation level; exceptions were for 'Finenss' and 'Hadeer' which were different for irrigation and Tecamin flower® rate. For this interaction vitamin C content and total yield was always higher for the 2.5 ml/l Tecamin flower® rate and the 50% irrigation level regardless of cultivar. For this interaction WUE was always higher for the 2.5 ml/l Tecamin flower® rate and the 100% irrigation level regardless of cultivar.

## CONCLUSIONS

Reducing the amount of irrigation by half, and with addition of Tecamin flower®, did not negatively affect most characteristics of vegetative growth and production and fruit quality. The 2.5 ml/l Tecamin flower® application was sufficient for good fruit quality, yield and WUE and reduced damage from water deficit for the production of tomato under limited irrigation.

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