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The effect of Tecamin Brix-V2 in tomato (*Solanum lycopersicum* L.) fruit under salt stress

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Abstract

The goal of the present experiment was to determine how the application of Tecamin Brix version 2, a biostimulant, impacts the production yield parameters and organoleptic quality of *Solanum lycopersicum* L. (tomato) grown under salt stress conditions in Morocco's Nador region. Climate change is becoming increasingly constraining for plant growth and development, especially in arid and semi-arid areas. These ecosystems are characterized by highly irregular rainfall associated with significant evaporation, which favours the accumulation of salts in the soil. Salt stress is considered a limiting factor affecting crop production and quality in semi-arid regions. Biostimulants are substances that can modify plant physiological processes to provide potential benefits for growth, development, or stress response. Foliar fertilization with Tecamin Brix® Version 2, compensates for nutrient deficiency in the roots due to salt stress. Results of present study showed that the application of Tecamin Brix® Version 2 to the foliage had a significant positive effect on the yield and fruit quality parameters of tomatoes ($P < 0.001$), especially in the Mediterranean region with a high range of salinity.

Keywords

Solanum lycopersicum; Amino acids; Fertilizer; Tecamin Brix; Foliar application; Salt stress

Introduction

Organoleptic parameters and quality of tomato (*Solanum lycopersicum* L.) are strongly influenced by the drought tolerance and disease resistance of improved genotypes in combination with good agricultural practices (1). The tomato fruit is an important source of substantial quantities of vitamins C, A, and lycopene, which is a natural antioxidant (2-4). According to the FAO, it is one of the most economically important vegetable crops, with over 163 million tons of greenhouse production in European countries (5). However, salt stress is one of the major factors that limits plant growth and crop productivity, especially in arid and semi-arid regions where soil salinity poses a severe threat to food security. The FAO reports that over 6% of the world's land is affected by salinity or sodicity, representing more than 800 million hectares of land worldwide (6). The Nador Region of Morocco is particularly affected by saltwater intrusion, with many coastal agricultural areas suffering from a loss of productivity (7). Additionally, high levels of salinity can cause both ionic and osmotic stress effects, leading to a decline in turgor, membrane damage, inhibition of water and essential ion uptake, disordered metabolism, altered levels of growth regulators, enzymatic inhibition, and ultimately metabolic dysfunction (8, 9).

The tolerance of tomatoes to stress conditions during field cultivation can be improved through the application of biostimulants. The use of biostimulant applications is able to enhance tolerance to different abiotic stresses, such as drought (10, 11), salinity (12, 13, 14), and thermal stresses (15). The application of biostimulants not only enhances nutrient uptake, yield, and crop quality but also stimulate natural processes that foster growth and help plants cope with extreme conditions such as high or low temperatures, water scarcity, and excess salt (16-19). Better seed germination and increased biological activity of plants can also be achieved with biostimulant use.

Tecamin Brix® is a biostimulant product that offers a multitude of benefits, such as stimulating fruit formation and ripening, increasing both the size and quantity of the fruit, improving the fruit's color and sugar content, preserving the fruit against attacks and diseases, and boosting the plant's production by activating its defence system. Its essential components are a concentration of 18% total Potassium (K_2O), 0.2% Boron, and 10% Seaweed extract.

The aim of the present work was to study the effects of foliar application of Tecamin Brix V2 (version 2) on tomato fruit yield and quality under salt stress in a semi-arid perimeter of the Mediterranean of Morocco, region of Nador (Bou-Areg), Morocco.

Materials and Methods

Plant materials

The commercial variety of elongated tomato cv. Nador F1 was used in this study.

Characterization of soils in the Mediterranean region of Nador (Bou-Areg)

The choice of soil for our plantations, which was the focus of our study, was based on the major constraints faced by market gardeners in the area, namely, strong soil salinization. This was the case for the plot in the Bou-Areg plain, with geographical coordinates of (N, W) 35˚06'2096'' 02˚50' 0264''. This soil, which has a high electrical conductivity on the order of 1.2 $mScm^{-1}$, was the subject of our study (Fig. 1).

Seed germination in growth chamber

The experiment was conducted on a half-hectare field using plants of a commercial elongated tomato, cv. Nador F1. Firstly, the seeds were disinfected with ethanol (70%), then rinsed thoroughly with distilled water, and placed in trays filled with peat. These trays were then placed in a growth chamber under controlled culture conditions of 24/18 °C, a 16/8-hour photoperiod, and fluorescent light with intensity of (140 mmol·m-2·s-1) to allow seed germination.

Field trials: transplantation and irrigation

Seedlings that were 30 days old and at the 3-4 leaf stage were manually transplanted into the open field. Before starting the irrigation, the seedlings were treated with a systemic fungicide Dife-noconazole (1mL/10L) using a backpack sprayer. Irrigation was carried out by impounding water from Machraa Hammadi

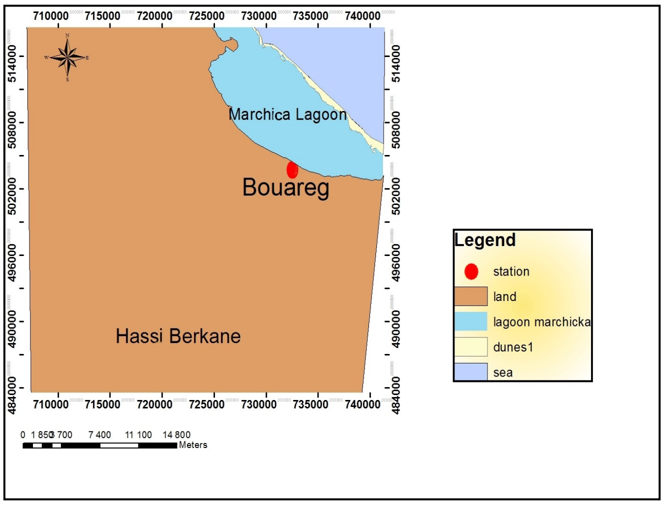

Fig. 1. Plot of soil sampling in the plains of Bou-Areg (Mostapha MAACH).

for one hour per day, with each plant being irrigated at a distance of 5 cm.

Biostimulant Treatments

In this experiment, Tecamin Brix® version 2 was applied via foliar application. The study followed a completely randomized design with three replicates per treatment and ten plants per biological replication (60 plants in total). Two groups were formed: a control group, which did not receive any Tecamin Brix® and a treatment group, which was treated with Tecamin Brix® version 2 biostimulant.

The treatment was applied with a backpack sprayer with a concentration of 3 mL. L−1 of Tecamin Brix® directly to the foliage of the tomato plants at the first appearance of the flower during the hours of 8-10 AM). This process was repeated every 15 days for three months in the morning.

Experiments were conducted in the Mediterranean region of Nador (Bou-Areg), where the soil is characterized by a silt loam texture. No additional fertilizer was applied.

This type of soil is composed of roughly equal parts of sand, silt, and clay, and has good water-holding capacity and fertility. To ensure that our results were not influenced by external factors, we did not apply any additional fertilizer to the soil. Instead, we relied on the natural nutrients present in the soil and the organic matter that was incorporated into it prior to planting.

Laboratory Experiments

Evaluation of Productivity of tomato fruit

Agronomic parameters were determined *in situ*, and tomato fruits were harvested after a transplanting period of 5 weeks. Harvesting was conducted once in a week, ensuring that all tomato fruits reached full maturity, indicated by a red-orange to red color. Fruit size was categorized in increasing order, from smallest to largest, as follows: below 60g, 60 to 120g, and above 120g.

After determining the agronomic parameters such as yield and biomass of tomato fruits *in situ*, we took the tomato fruit harvests to the laboratory to determine the other parameters.

In an evaluation of tomato fruit quality against salt stress under the application of biostimulants, according to (20) fruit quality parameters were selected which may also change with the season, such as solids content, taste, color, firmness, and also fruit size.

Concerning another parameter like tomato yield, this character is mainly evidenced first of all by flowering, fruit set, and also fruit development (21).

Measurement of tomato fruit firmness

The relationship between subjective firmness values, which are very important for marketing, and objective firmness evaluation (acceptability levels or finger feel firmness) of tomatoes was investigated. The measurement of this parameter was done by a portable penetrometer that meets the requirements of the standards as described by (22).

Sugar Content

Brix is the main technological parameter in tomato concentrates. It represents the degree of concentration of the tomato juice. This parameter is subject to very strict regulations. Brix is defined as the sucrose concentration of an aqueous solution having the same refractive index as the product under analysis.

Tomato fruits of the same quality criteria were selected and homogenized in a blender for a period of 2 minutes. The obtained homogenate was then filtered, and the total soluble solids content was measured using a digital refractometer (PAL-1, Atago, Tokyo, Japan).

Lycopene content

To determine lycopene in tomato fruit samples, we followed the steps mentioned below according to (23, 24):

Dissolve an amount of 0.001g of tomato fruit in 1ml of distilled water, shaken well with a vortex in a water bath under a temperature of 30˚C for 1 hour, then 8.0 ml of hexane: ethanol: acetone (2:1:1) were added. Then, recover the contents and shake immediately, then incubated in the dark. Next, wait 10 min and adding 1ml of distilled water, mix with vortex. Afterward, leave the samples for 10 min, and finally, an absorbance reading at 503 was taken. Finally, the determination of lycopene (mg/kg) was done following the relation: Lycopène (mg/kg) = (A503× 537 × 8 × 0.55) / (0.10 × 172) or = A503× 137.4.

pH measurement

The pH of the fruit homogenate was determined using a portable pH meter.

Statistical analysis

Data were analysed using Statgraphics Plus (Statistical Graphics Corp, StatPoint Inc., Herndon, VA). Analysis of variance (ANOVA) was used to assess difference between treatments and significance level was determined at $P \leq 0.05$. Significant differences according to the Duncan's multiple range test (DMRT) are indicated with different letters in the figures and tables.

Result

Biostimulants can be used in vegetable production to improve organoleptic and agronomic parameters on one side, such as Firmness, Brix, lycopene, and pH. On the other hand, productivity and yield, and to enhance plant tolerance to stress factors and plant health (Table 1, Table 2 and Fig. 2).

Effects of biostimulants on Firmness, TSS (°Brix), lycopene, and pH

Data in Tables 1 and 2 present the impact of utilizing biostimulants, specifically Tecamin Brix® version 2 (TB®-V2), on the *S. lycopersicum* tomato crop of the commercial elongated tomato cv. Nador F1 variety under salt stress in the Nador (Bou-Areg) region of the Mediterranean.

From the data presented in Table 1, we observed that the firmness parameter of *S. lycopersicum* tomatoes was lower in the control 2.00 (kg/cm^2) compared to the group treated with TB-V2 biostimulants. The application of TB-V2 resulted in a significant improvement in firmness (4.88 kg/cm^2; $P < 0.001$).

Furthermore, the application of TB-V2 biostimulant resulted in a significant increase in two important parameters of *S. lycopersicum* tomatoes - fruit quality Brix and lycopene ($P < 0.001$). The highest values recorded were 6.42 (°Brix) and 47.27 (mg/g fresh weight) respectively. In contrast, there was no statistically significant difference observed for these two parameters when using only the control group without the Tecamin Brix®-V2 biostimulant (Fig. 2).

Fig. 2. Image of a representative experiment after the use of biostimulants (Tecamin Brix version 2) and without (only water). Fruit Pigment and size is largely expressed in tomato fruit (*S. lycopersicum*) wish Treatments consisted of foliar application by Tecamin brix. Two treatments were used: Control (no biostimulants) and TB-Version 2, with 10 plants assigned to each treatment. Each treatment was replicated three times, resulting in a total of 60 plants.

Table 1. Effect of Tecamin Brix-Version 2 application on tomato fruit quality: Firmness, TSS (°Brix), pigment and pH (p <0.001).

Treatment	Firmness (kg·cm^{-2})	TSS^a (°Brix)	Pigment (mg·g^{-1}fresh weight)	pH
Control	2.05b^y	4.30b	17.28b	4.12b
TB-V2	4.88a	6.42a	47.27a	4.38a

TSS^a: Total soluble solids
^{y}Means followed by different letters are significantly different at $P \leq 0.05$.

Table 2. Effect of treatment biostimulants Tecamin Brix-Version on total fruit yield (kg/10 plants) (p <0.001).

Treatment	Fruit weight (kg/10 plants) Small	Medium	Large
Control (water only)	6.67f[y]	23.55c	20.87d
Tecamin brix® V2(TB-V2)	15.7e	46.74a	40.22b

Total fruit yield (kg/10 plants) was significantly impacted by the application of Tecamin Brix-Version biostimulant treatment (p < 0.001).
[y]Means followed by different letters are significantly different at $P \leq 0.05$.

Finally, we observed that the use of TB-V2 resulted in a more favourable pH reading for tomato fruits, with a significant value falling within the optimum range (3.64) compared to a pH of 4.08 recorded in the control group ($P < 0.001$).

Effects of biostimulants on yield

According to Table 2, the Tomato variety, cv. Nador F1, had the highest yield per plant. The use of Tecamin Brix® version 2 biostimulant application significantly affected the fruit size, with small fruits weighing 15.75 (kg/10 plants), medium fruits weighing 40.22 (kg/10 plants), and large fruits weighing 46.74 (kg/10 plants) all showing significant differences compared to the control ($P < 0.001$).

Discussion

In the present study, plant vegetable production and quality characteristics, like firmness, Brix, lycopene and pH, productivity and yield, were significantly affected by the application of biostimulants. Biostimulants have been used generally for one of the following reasons: Firstly, to improve the pomological characteristics of fruit plants, which are currently the most objective of modern agricultural practices. Secondly, to reduce as much as possible the time of fruit ripening while acting on the improvement of agronomic parameters (total and per plant yield), also the organoleptic qualities of fruits (fruit appearance, size, sugar content, ripening, and weight) (25). In addition, firmness is affected by cell wall structure, cell size, turgidity, and membrane properties (26).

In general, the degree of firmness is related to the ripeness of many agricultural products and is considered one of the means of indicating fruit quality (27), so fruit firmness may be the final index by which consumers decide to buy a given batch of tomatoes (28). Moreover, fruit firmness decreases as fruit becomes more mature and decreases rapidly as it ripens (29). As shown in Table 1 firmness values of tomatoes are significant differences and highly increased with treatment by biostimulants Tecamin brix version 2. Our results show agreement with (7) who observed a significant increase in fruit firmness in the tomato *S. lycopersicum* plant with an application of biostimulants.

Nowadays, Biostimulants have a significant effect on ethylene synthesis and potassium content (30). Furthermore, the use of algal extract has been shown to have a beneficial effect on turgidity and cell wall components, improving cell membrane flexibility and fruit firmness (31).

The soluble sugars glucose and fructose are the largest contributors to the total soluble solids commonly expressed in °Brix. According to (32), these two parameters, soluble sugars and acidity, determine the specific sensorial quality of tomato fruits. Moreover, the degree of Brix and lycopene content play an important role in tomato selection (33, 7).

The data presented in Table 1 shows that the application of biostimulants resulted in an increase in the total soluble solid values in fruits treated with Tecamin Brix Version 2 compared to untreated plants. The lowest value for total sugars of *S. lycopersicum* was recorded in the control group. These results are consistent with those reported by (7) in tomato fruits and by (34) in bell pepper fruits. Furthermore, the results in Table 1 indicate that an increased level of soluble sugars can enhance the plant's tolerance to salt stress, which is consistent with the nature of the soil in the plot mentioned in Fig 1.

Lycopene is a crucial red pigment found in tomato fruits, comprising 80-90% of total carotenoids (35). This water-insoluble antioxidant is highly significant and exhibits antioxidative properties by neutralizing ROS and stabilizing membrane structures, owing to its β-ionone ring and eleven conjugated double bonds (36). Lycopene biosynthesis takes place in photosynthetically active tissues as a part of the isoprenoid pathway and plays a central role in carotenoid biosynthesis (37). In our study, we demonstrated that the application of biostimulant, Tecamin Brix® version 2, can modify the carotenoid content in tomato fruits.

The lycopene content was significantly increased, as shown in Table 1. Similar results were obtained in *S. lycopersicum* plants (38, 7). Furthermore, Tecamin Brix® version 2 was found to improve the pH of tomato fruits under salt stress (Table 1), resulting in pH values within the optimal range for good and acceptable tomato fruit quality (39).

Biostimulants are utilized to enhance crop quality and increase yield. As shown in Table 2, the application of Tecamin Brix® resulted in the production of small, medium, and large-sized fruits. Comparatively, the control group produced a smaller quantity of small, medium, and large-sized fruits than the group treated with Tecamin Brix® biostimulant (Table 2). Application of Tecamin Brix® biostimulant resulted in the production of a greater quantity of fruits of various sizes. The biostimulant contains potassium and boron, which are vital nutrients for plant growth and enhancing crop yield (40, 41, 1-7).

Conclusion

Based on all these results, we concluded that the application of Tecamin Brix version 2 biostimulants in vegetable crop tomato cultivation interacts in a positive way and gives better acceptable results. Biostimulants, on the one hand, increases the tolerance of plants to abiotic stresses in semi-arid areas containing considerable concentrations of harmful salt stress ions. On the other hand, it increases the yield and improves the quality of tomato fruits.

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Authors' contributions

MM prepared the manuscript, MB performed statistical analysis; KB worked together in his farm. MA, AS, AM, HG and OR supported in the experimental work.

Compliance with ethical standards

Conflict of interest: The authors declare that they have no conflict of interest.

Ethical issues: None.

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