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Production and Qualitative Aspects of Tomato Fruits under Leaf Fertilizer Applications with Resistance Bioinducers

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Authors' contributions

This was a collaborative work between all authors. Author RLSF wrote the research project, performed the data analysis and wrote the initial manuscript. Author JLB performed the data collection and laboratory analysis. Author MAB held to rules suitability of the final manuscript as advocated in the guideline author of this journal. Author DMMS had intellectual contribution effecting reading and technical opinion on the originality and scientific relevance of the research. Author FOF conducted the data collection and laboratory analysis. All authors read and approved the final manuscript.

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ABSTRACT

The tomato is one of the cultures of great interest to the global agribusiness, especially to meet the industrial demand, resulting in income and quality of life to the producer. Given the complexity of culture, new technologies and management strategies are necessary. Hence, this experiment was carried out with the objective of evaluating the productivity and qualitative aspects of tomato fruits under leaf fertilizer applications with resistance bioinducers. The experiment was conducted in the field in a completely randomized design. The treatments consisted of T_1 = Control and T_2 = Leaf

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fertilizer + resistance bioinducers, with four replications. Productive aspects and quality of fruits for the industry were evaluated, and these aspects expressed through the variables, number of fruits per plant, fruit weight per plant, fruit average weight, fruit weight yield, longitudinal and transversal diameter, mesocarp thickness and fruit shape, total soluble solids and hydrogenionic potential. The treatment with leaf fertilizers based on Ca, Mg, B, S, Fe, Mn, Mo and Zn together with yeast hydrolyzate and humic acid bioinducers promoted significant increases in tomato production and fruit size, not altering, however, the qualitative aspects of these.

Keywords: Lycopersicum esculentum Mill; plant nutrition; acquired systemic resistance.

1. INTRODUCTION

Among the main oleraceous crops of economic interest worldwide, the tomato (*Solanum lycopersicum* L.) has aroused great interest in the agribusiness scenario [1]. Mainly due to the sharp growth of its cultivation, especially to meet the demand of the agro-processing sector, which impels the increasing production, thus making it necessary to optimize and raise the technological level for the sustainable growth of this activity in order to ensure the maximum level of production to meet the industrial demand.

It should be noted that the tomato is characterized by culture complexity, above all by the exposure to various biotic and abiotic stresses [2]. Because of the edaphic and climatic variations prominent in the crop areas, there is a considerable variation in the quantitative and qualitative attribute levels of tomato fruits, such as productivity, yield, dimensions and shape, as well as flavor, color, texture and smell, acidity, pH and °Brix [3]. [4] report that several research papers have described increases in crop productivity due to leaf fertilizer applications [5-7].

The use of leaf fertilization has been intensified in various crops of economic interest, since this is the most effective application system of micronutrients or small quantities of nutrients as supplements of the most important elements used by the plant. Due to the high economic value of the tomato, the application of leaf fertilizers and resistance bioinducers has been used by producers in order to provide the useful nutrients for the plant under stress and at critical moments of nutrient and energy demand, aiming at an increase in production and fruit quality [8,9].

The ability of plants to respond to the attack of pathogens through the activation of defense mechanisms is known as systemic acquired resistance (SAR). Research on plant defense responses attract increasing attention, as the practical potential for application of this knowledge is effective in the control of crops, so that research on the SAR mechanism revealed chemicals that can induce defense responses in plants [10].

For the control of plant diseases, producers have used products that induce resistance in plants, since the use of resistance inducers presents itself as a tool in crop management, in view of its systemic effect, compatibility with other products and the broad spectrum of action, which ultimately assists in the control of other diseases.

Several mechanisms can be activated during the resistance induction phenomenon, optimizing the capacity of crop production [11]. In this context, this experiment was carried out to evaluate the productivity and the qualitative aspects of tomato fruits under leaf fertilizer applications with resistance bioinducers.

2. MATERIALS AND METHODS

The experiment was conducted between May and July 2014, located at coordinates 20°10'14.9" S and 48°29'31.4" W, in the city of Guaíra, SP, Brazil. The experimental area is 517 m above sea level, with an average annual temperature of 25°C, humidity of 69%, and rainfall of 1.550 mm, and the climate of the region is classified, according to Koppen, as tropical with dry season, Aw. During the experiment execution the climate was monitored through meteorological variables, average temperature (AT), relative humidity (RH), solar radiation (SR) and rainfall (PP), and the data of the variables was obtained from the automated meteorological station closest to the experimental area (Table 1).

Initially, the soil was prepared by plowing procedure followed by harrowing aimed at better conditions for transplanting the seedlings. Correction of soil acidity was made based on analysis of soil by adding limestone for pH elevation until close to 6. The fertilization was carried out from the data of soil fertility analysis as recommended by [12]. After preparation, correction and fertilization, the soil was irrigated to reach the moisture condition close to field capacity (FC). After observing the time required for correction and availability of nutrients, the seedlings were transplanted to the experimental area, keeping a periodic irrigation of 20 mm per irrigation interval, considering the water depth may vary based on need.

A completely randomized design was adopted, and the treatments consisted of T_1 = Control and T_2 = Leaf fertilizer + resistance bioinducers, with four replications. After 30 days elapsed since transplanting the seedlings to the field, the periodic treatment with leaf fertilizers started with resistance bioinducers, the commercial sources used were Key Plex Blossom DP (Ca = 3, Mg = 2, B = 1, Yeast hydrolyzate = Humic acid = 0.063 and 0.05%) and Key Plex 350 DP (Mg = 1.5, S = 4, B = 0.16, Fe = 3.5, Mn = 0.75, Mo = 0.003, Zn = 0.75, Yeast hydrolyzate = 0.063 and Humic acid = 0.11%). The treatment applications consisted of leaf spray using a boom type sprayer with constant pressure and arterial runoff. Concomitant to the treatments, during the experiment, a periodical phytosanitary management was adopted for pest and disease control, such management was based on the application of commercial synthetic pesticides.

Currently in Brazil, the cost for the industrial tomato crop conduction; considering the operation with machines, permanent workforce, pesticides and fertilizers; is of approximately R$ 2,770.34, representing 26.5% of total costs for the expected production of 85 t ha^{-1}, generating gross revenue of R$ 15,300.00 ha^{-1}. Based on this information, the analysis of the benefit-cost ratio (BCR) was performed from the relationship between the average obtained productivity (P) and the cost for crop conduction (C): BCR = P/C. It is important to note that the recommendation of the commercial product used in this study is 1.5 L ha^{-1}, requiring eight applications during the crop cycle.

At random, four experimental units were selected in the control and in the treated area, which were composed of a useful plant to carry out the fruits samples, which were packed and transported to the Plant Physiology Laboratory of the Faculty of Agricultural and Veterinary Sciences in the Paulista State University in order to determine the productive and quality aspects of the fruits for the industry, and these aspects were expressed through the variables: number of fruits per plant (NFP $plant^{-1}$), fruit weight per plant (FWP kg $plant^{-1}$), average fruit weight (AFW g $fruit^{-1}$); fruit weight yield (FWY %) longitudinal (FLD mm) and transversal diameter (FTD mm), mesocarp thickness (FMT mm) fruit shape (FS), total soluble solids (°Brix) and hydrogenionic potential (pH).

To determine the FWP, AFW and FWY variables we used a scale of digital accuracy ±0.001 g, while FLD, FTD and FMT were measured using a digital caliper with an accuracy of 01 mm. The fruit shape was determined according to the recommended parameters in Tomato's Classification Standards [13]. To measure the total soluble solids content a portable refractometer was used, while the pH was measured in a pH meter.

The data from the response variables were subjected to variance analysis by the F test at 95% confidence rate. After a significant difference between the treatments was found, a mean comparison test (Tukey) was performed at 5% error probability. In order to perform the analysis we used the program for statistical analysis Sisvar [14].

3. RESULTS AND DISCUSSION

Based on the results of the variance analyses, it was found that the treatments were statistically different (P=.01) for the variables: number of fruits per plant, fruit weight per plant, average fruit weight, longitudinal and transversal diameter, and fruit weigth yield (P=.05). On the other hand, the treatments did not promote significant differences (P=.05) in the variables: mesocarp thickness, fruit shape, total soluble solids and hydrogenionic potential (Table 2).

Table 1. Monthly averages of climate variables obtained during the experiment conduction. Guaíra, SP, 2014

Months	Climate variables			
	AT (°C) [1]	RH (%) [2]	SR (kJ m^{-2}) [3]	PP (mm) [4]
May	20.10	71.28	736.78	34E-5
June	20.15	66.06	683.65	30E-5
July	20.20	61.84	600.81	14E-4

[1]Average temperature; [2]Relative humidity; [3]Solar radiation; [4]Pluviometric precipitation

Table 2. Summary of the variance analyses of the variables, number of fruits per plant (NFP plant^{-1}), fruit weight per plant (FWP kg plant^{-1}), average fruit weight (AFW g fruit^{-1}), fruit weight yield (FWY %), longitudinal diameter (FLD mm), transversal diameter (FTD mm), mesocarp thickness (FMT mm) and shape (FS) of fruits, total soluble solids (°Brix) and hydrogenionic potential (pH) of tomato fruits under leaf fertilizer applications with resistance bioinductors. Guaíra, SP, 2014

VS	DF	Medium Squares				
		NFP	**FWP**	**AFW**	**FWY**	**FLD**
Treatments	1	264,50**	1,71**	18,69**	5,71*	9,87*
Residue	6	3,16	0,01	1,29	0,84	1,42
CV (%)		2,05	2,42	1,78	1,05	2,00
		FTD	**FMT**	**FS**	**°Brix**	**pH**
Treatments	1	13,88**	0,24^{ns}	0,1e-2^{ns}	0,1e-2^{ns}	0,1e-2^{ns}
Residue	6	0,16	0,06	0,7e-3	0,13	0,1e-1
CV (%)		0,97	3,06	1,95	8,19	2,24

***,*: significant at 1 and 5% of error probability, ns: not by the F test, VS: sources of variation, DF: degrees of freedom, CV: coefficient of variation*

Through the results of the mean comparison test, it was found that the treatment with leaf fertilizer applications plus resistance bioinducers caused greater production in number (92.5 fruit plant^{-1}) and fruit weight (5.9 kg plant^{-1}). Contrasting the values obtained in control plants (81 fruits plant^{-1}) and fruit weight (4.9 kg plant^{-1}) with the values obtained in the treated plants, the percentage differences were calculated in the order of 12.4 and 16.9%, respectively (Figs. 1A, B).

The significant increases observed in the number and weight of fruits per plant can be attributed to the increase in nutrients provided to the treated plants. This information is supported by [15] who mentions that leaf fertilization is a practice widely used in supplementation to fertilization provided via soil, mainly in vegetables, to raise the economic return. Research with other cultures also showed gains in production under leaf fertilization, for example, in the investigations conducted by [16] and [17] with the culture of potato cvs. Atlantic and Ágata. [4] add that the leaf fertilization could replenish the nutrients in the leaves, keeping the rate of photosynthesis for longer, with possible impacts on productivity.

The composition of the main bioinducers commercially available may include humic materials, for example humic acids, growth promoter hormones of plants, vitamins and various other elements [18]. According to these authors, bioinducers may also contain other organic substances derived from seaweed extract. In a complementary sense, [19] found significant reduction in the severity of bacteria attack in tomato plants under application of resistance inducers. These authors report that, besides the activation of natural defenses of the plants, the effect is related to the regulation of plant growth, which assures higher stability in the field and therefore greater capacity for light absorption, photosynthesis realization and translocation for the drains, justifying the increase in productivity.

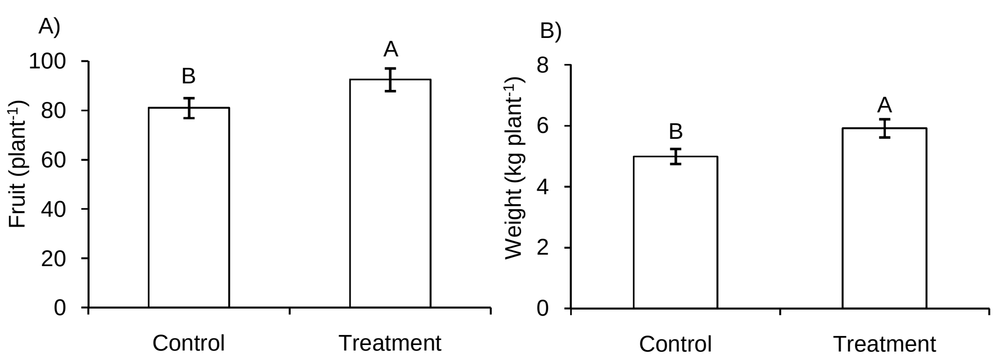

Fig. 1. Fruit number per plant (A) and fruit weight per plant (B) in tomato under applications of leaf fertilizers with resistance bioinductors. Guaíra, SP, 2014

A larger fruit weight allocation (65.2 g fruit^{-1}) was observed in the plants treated with leaf fertilization and resistance inducers, differing expressively from the 62.1 g found in fruits of plants conducted in the absence of treatment. For this variable the percentage difference of 4.7% was calculated (Fig. 2A). Comparing the plants treated with the control ones for the variable fruit weight yield, it was found that under treatment the fruits had a higher yield (88.4%), and an increase of 1.9% was calculated compared to control plants, which expressed yield of 86.7% (Fig. 2B).

Leaf fertilization on tomato crop is a known promoter of quantitative and qualitative increases in production. In fact, the free amino acids present in fertilizers help significantly on the nutrient input in the plant, in addition to being excellent initial energy supplies, acting as essential hormones precursors to the rooting process, providing greater stabilization of plants in the field, favoring photo assimilation processes and distribution of photo assimilates [16]. Leaf fertilizers containing organic compounds, for example humic acids and hydrolyzed yeast, fall into the categories of biological activators, growth stimulators and regulators, sources of nutrients of low mineral concentration, conditioners and moisturizing agents [8]. Based on this information it can be inferred that the gains in fruit weight and yield can be attributed to the treatments carried out, mainly by the various effects described in the literature. [20] studied the use of inducers in tomato and did not find significant differences in growth and biomass accumulation on the plants treated, confirming the hypothesis that the product has not been used to increase the growth of vegetative organs, but it was translocated to the fruit, which justifies the increase in fruit weight accumulation and fruit yield under leaf fertilization with resistance bioinducers.

Tomato fruits subjected to treatment expressed larger diameters, longitudinal (60.7) and transversal (45.3), statistically diverging from the values (58.4) and (42.6) recorded in the fruits of plants grown in the absence of leaf fertilizer applications with resistance bioinducers. Increments of 2.3 and 2.7 mm were calculated in the longitudinal and transversal diameter, respectively, when the plants were treated, with these increments having represented 3.8 and 6.0% of gain compared to control (Figs. 3A, B).

Generally speaking, the increase noticed in the fruit dimensions is due to the positive effects of nutritional supplementation through the leaf, notably due to the solution composition applied, which contained organic compounds that have the function to optimize the absorption of the nutrients in the solution, making the leaf fertilization more efficient [8]. In addition, the observed superiority can also be a reflection of the lower incidence of pathogen attack, which is in agreement with [11], who observed the effect of the application of this product to control the disease known as bacterial speck, the data being backed by analysis and evidence of increase in the patterns of antioxidant enzymes, that protect the oxidative mechanisms of cells against free radicals and oxygen reactive species [21].

Table 3 shows the means and variance of the variables mesocarp thickness, fruit size, total soluble solids and hydrogenionic potential of fruits, which were not significantly influenced by treatments with leaf fertilizers and bioinducers. These findings are of great interest to the food industry, notably because the pH of the fruits was not changed to levels that decharacterize the qualitative aspects. Fruit with pH between 4 and 5 are considered of good industrial quality [22], and the acidity allows greater fruit conservation after harvest [19]. The values disclosed in this research are also ratified by [3] who found total soluble solids (°Brix) ranging between 4 and 6 after studying different cultivars of tomato.

The acquirement of tomatoes that have a good aspect, with respect to size, color, shelf life, shape, firmness, texture, dry matter content, organoleptic properties such as flavor, and nutritional consist of important parameters for the marketing of the fruits, resulting in higher added value [23].

For the plants that were subjected to treatment with leaf fertilizer containing resistance bioinducers, we calculated the benefit-cost ratio (BCR) of 0.0497, while on the control plants this rate was 0.0392, showing superiority of 21% on the return provided by the treatment employed. Based on this information, it can be inferred that the treatment can be recommended for industrial tomato crop.

It is important to note that the commercial product used in this study is registered as a bio-pesticide and may be used without damage to the environment, especially because it consists of nutrients, humic acid and hydrolyzed yeast [24]. Although a residual analysis in the experimental area was not performed, the literature data [25] informs of a possible residual effect of leaf fertilization, which is considered a positive effect, especially for the buildup of small amounts of nutrients in the soil. Indeed, an increase in macro and micronutrients in the soil was verified in orange crops under the application of leaf fertilizers containing resistance bioinducers, unpublished data.

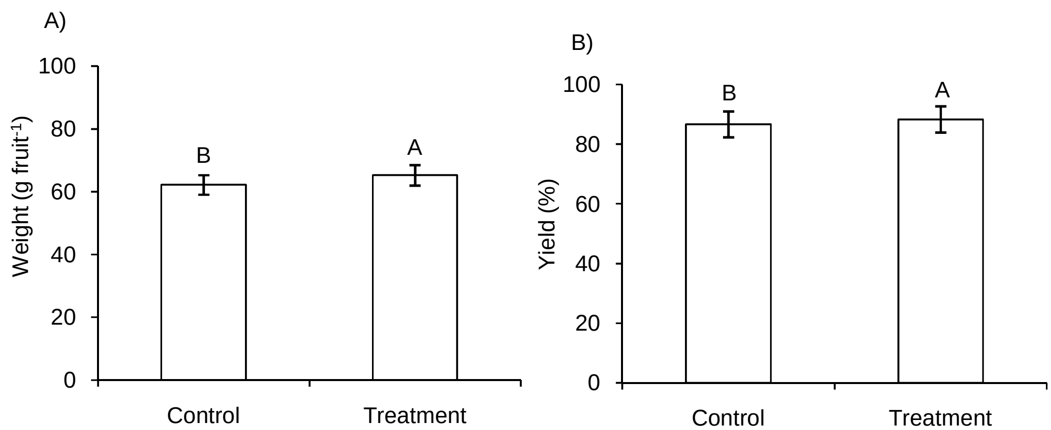

Fig. 2. Average fruit weight (A) and weight yield of fruit (B) of tomato under applications of leaf fertilizers with resistance bioinductors. Guaíra, SP, 2014

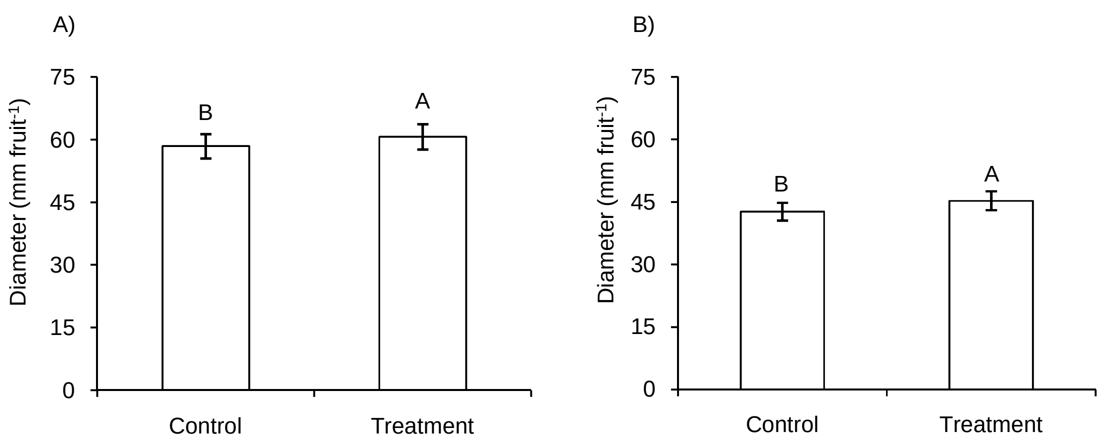

Fig. 3. Longitudinal (A) and transversal diameter (B) of tomato fruits under applications of leaf fertilizers with resistance bioinductors. Guaíra, SP, 2014

Table 3. Mean values of the variables Mesocarp Thickness (MTF mm), Fruit Shape (FS), total soluble solids (ºBrix) and hydrogenionic potential (pH) of tomato fruits under applications of leaf fertilizers with resistance bioinductors. Guaíra, SP, 2014

Variation sources	Averages ± Standard deviation			
	MTF	FS	ºBrix	pH
Control	7,97±0,18	1,37±0,01	4,57±0,51	4,46±0,08
Treatment	8,31±0,30	1,34±0,03	4,55±0,10	4,48±0,11
LSD	0,43	0,04	0,64	0,17
F-test	0,09	0,15	0,92	0,76

LSD: Least significant difference and F: Fisher's F test

4. CONCLUSION

Treatment with leaf fertilizers with Ca, Mg, B, S, Fe, Mn, Mo and Zn, plus humic acid-based and hydrolyzed yeast-based resistance bioinducers promotes significant increases in tomato production and fruit size, without however changing the qualitative aspects of these.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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