RELATION BETWEEN PLANT YIELD AND FRUIT QUALITY CHARACTERISTICS OF TOMATO

RELAÇÃO ENTRE PRODUÇÃO DA PLANTA E CARACTERÍSTICAS DE QUALIDADE DO FRUTO DO TOMATEIRO

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ABSTRACT: The main objective of breeding programs is to obtain tomato varieties capable of expressing their yield potential under the most diverse conditions. However, little emphasis has been employed on the quality of the fruits produced. Thus, the objective of this work was to evaluate tomato fruit quality with regarding TSS:TA ratio, sugar reducing content, acidity, pH, total soluble solids and contents of carotenoids, ascorbic acid and potassium as a function of plant yield increase. Two experiments were carried out at the Olericulture Sector, Department of Plant Sciences, Universidade Federal de Viçosa, Viçosa, MG, from January to May 2002. A randomized block design was used, with six replicates, and three genotypes: cultivar Santa Clara, hybrid Carmem and an accession BGH-320 from the Vegetable Germplasm Bank of the UFV. The experiment was carried out in a non-heated greenhouse covered with a plastic film and in the field conditions. The increase of plant productivity reduced the fruit quality, except for TSS:TA ratio of Santa Clara and TSS of the Carmem fruits growth in the field, that had increased with the increase of plant productivity. The sugar reducing content of genotype BGH-320 growth in the non-heated greenhouse and acidity of the Santa Clara's fruits growth in the field were reduced with increase of plant productivity. TSS:TA ratio of the Carmem's fruits growth in non-heated greenhouse and potassium content of BGH-320's fruits growth in non-heated greenhouse presented quadratic behavior with increase of plant productivity.

KEYWORDS: *Lycopersicon esculentum*. Qualitative characteristics. Productivity.

INTRODUCTION

Tomato plant production aims to assist the markets of industry and fresh market consumption. Varieties with high soluble solids content are desirable because of their direct relation with industrial income (CARVALHO, 1980; DAVIES; HOBSON, 1981).

The market for fresh fruit gives preference to flavorful fruits, with better aroma and nutritional composition. Lycopene, vitamin C, beta-carotene, potassium, among other tomato components, have attracted consumer's attention based on evidence that the presence of these compounds through a regular ingestion of tomatoes may decrease the risk of esophagus, stomach, lung and respiratory tract cancers, as reported by Fontes and Silva (2002).

Obtaining better fruit quality varieties has been hindered by negative correlation between this trait and plant yield (STEVENS; RUDICH, 1978). Environmental variability and diverse crop practices used by farmers make tomato plant breeding even more difficult, since different fruit production and quality responses are obtained among genotypes and crop environments (HO, 1999).

Plenty of data are available in the literature about tomato plant yield potential and fruit quality but few correlate both. This analysis can be carried out by means of bivariate regression, by evaluating fruit quality as a function of plant yield, taking into account two dependent variables (STEEL; TORRIE; DICKEY, 1997).

The simple linear regression model assumes the variable X to be fixed, and not random, as cited by Hoffman and Vieira (1998). However, according to these authors, this criterion is not always essential. The distribution of X and independent e_i (errors) produce valid results provided they are conditioned to the values X observed and these values act as if they were fixed.

Draper and Smith (1998) believe that the most appropriate would be the regression between a dependent random variable Y and a non-random independent variable X. However, it is quite common for both variables to be random, and they can be analyzed provided they have a bivariate distribution.

Steel et al. (1997), accept regression between two random variables, called bivariate regression (provided the two variables are assumed

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to be normal) based on random sampling of individuals in which measure pairs (in this case, quality and production) are taken. These authors consider the dependent variable choice to be determined by the nature of the problem, stressing that two different regressions are possible (dependent X and independent Y and vice-versa). In the linear regression, errors (e_i) are assumed to be normal and independently distributed with common variance. If this is not the case, the weighted regression must be utilized or data should be transformed so that variance is homogenized.

Therefore, this work aimed to analyze the tomato fruit quality characteristics (TSS:TA ratio, sugar reducing content, titratable acidity, pH, and lycopene, ascorbic acid and potassium contents) as a function of plant yield.

MATERIAL AND METHODS

Two experiments were simultaneously carried out under different environments at the Olericulture Sector, Department of Plant Science, Federal University of Viçosa, Viçosa - Minas Gerais, Brazil. A randomized block design was used in both experiments, with six replicates and three genotypes: cultivar Santa Clara, the hybrid Carmem and an accession from UFV Vegetable Germplasm Bank, BGH-320, which was included for its outstanding fruit quality among 34 accesses (CALIMAN et al., 2002). Between and in-row plant spacing used were 1,0 m and 0,6 m, respectively. Tomato plants were conducted vertically with one steam and pruned above the sixth flower cluster. Each experimental parcel was constituted by six useful plants.

There was used a non-heated greenhouse with 10 m wide, 40 m long and 5 m high, with retractable lateral shades and covered with a plastic film. The field experiment was carried out under natural conditions, without any protection. The seedlings were produced in 128 cell-styrofoam trays, remaining there for 20 days after sowing on the 13th of December 2001, being simultaneously transplanted into the soil of the two environments. Drip irrigation system was used in both experiments with fertigation being carried out weekly, according to the nutrient levels previously obtained by soil analysis and as a function of crop demand, based on Filgueira et al. (1999).

Harvests were performed when fruits reached the completely ripe stage, with 100% of their surface presenting an intense red coloration. After each harvest, the fruits had been classified (LUENGO et al., 1999) and weighed. The addition of the all harvests resulted in the marketable production. The evaluation of fruit quality characteristics was carried through in composed sample, originated from at least four plants in each replicates, with fruits harvested in the third cluster.

In this experiment, only the marketable standard fruits were considered as marketable yield, disregarding fruits with blemishes, and attacked by fungal or bacterial diseases. Fruits with transversal diameter smaller than 40 mm for oblong fruits (Santa Clara) and smaller than 50 mm for round fruits (BGH-320 and Carmem) were not included.

The following fruit characteristics were evaluated: a) Total soluble solid/Titratable acidity (TSS:TA), a flavor indicator as described by Kader et al. (1978); b) Sugar reducing content, by applying the methodology described by Dubois et al. (1956) and modified by Johnson et al. (1966); c) Titratable acidity (TA, % of citric acid); d) pH; e) Total soluble solids (TSS, ºBrix), by applying the methodology of Pregolato and Pregolato (1985); f) Total carotenoids, expressed as lycopene determined spectrophotometrically using the maximum absorption coeficient of 472 nm (TAN, 1988; HART; SCOTT, 1995); g) ascorbic acid, determined by titration with 2,6-dichlorophenolindophenol, according to methodology of AOAC (1975); h) potassium content, extracted by means of nitric-perchloric acid digestion and determined by flame photometry.

Fruit carotenoid was not separated in this work and lycopene is cited without disregarding the contribution of the other pigments, since the red color of the tomato is attributed to its main carotene, lycopene, which constitutes 80 - 90% of total carotenoids (DORAIS; GOSSELIN; PAPADOPOULOS, 2001).

For the adjustment of the bivariate regression equations (STEEL; TORRIE; DICKEY, 1997), plant yield was considered as an independent variable (X) and the quality characteristics of the fruits as dependent variable (Y). Each fruit quality characteristic was evaluated in the different genotypes and different environments so that the plant yield effect on the fruit quality characteristic could be evaluated.

RESULTS

The bivariate regression equations (fruit quality vs production characteristic) were adjusted for the genotypes Santa Clara and Carmem cultivated in the field. For Santa Clara, equations were adjusted for the TSS:TA ratio and titratable acidity data and for Carmem, equation was adjusted for the TSS data. In a non-heated greenhouse crop, regression equations were adjusted for Carmem and BGH-320 data's. For Carmem, equation was adjusted for TSS:TA ratio data and for BGH 320 equations were adjusted for sugar reducing and potassium contents (Figure 1).

The linear bivariate regression equation was adjusted for field-produced Santa Clara fruit TSS:TA ratio data (Figure 1A). This equation analysis led to conclude that one unit increase (1 $t.ha^{-1}$) in plant yield increased fruit TSS:TA ratio by 0.70 unit.

The TSS:TA ratio increase tendency observed with the increase of Santa Clara plant yield did not occur with the Carmem's fruits produced in non-heated greenhouse. Quadratic bivariate regression equation was adjusted for data of this characteristic (Figure 1B). The adjusted equation showed that fruit TSS:TA ratio increased with the increase of plant yield up to the limit value of 78.73 $t.ha^{-1}$, after which plant yield increase was followed by reduction in TSS:TA ratio.

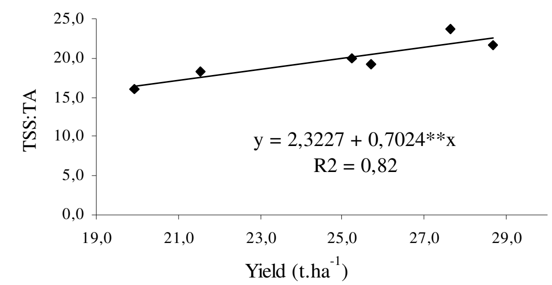

Figure 1A. Linear bivariate regression for Santa Clara TSS:TA data (y) as a function of yield (x) of field-grown plants. Note: ** *P*<0,01

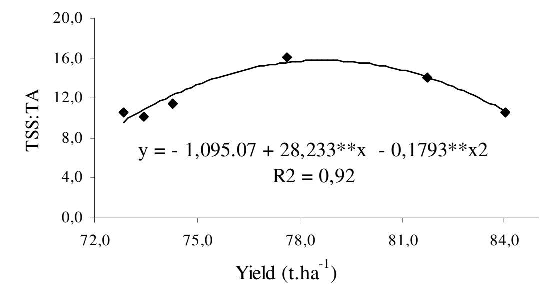

Figure 1B. Quadratic bivariate regression for Carmem TSS:TA data (y), as a function of yeld (x) of non-heated greenhouse-grown plants. Note: ** *P*<0,01

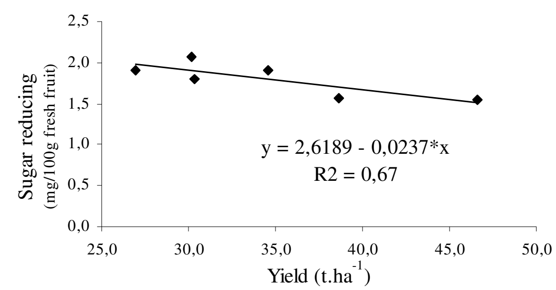

Figure 1C. Linear bivariate regression for BGH-320 sugar reducing data (y) as a function of yield (x) of non-heated greenhouse-grown plants. Note: * *P*<0,05

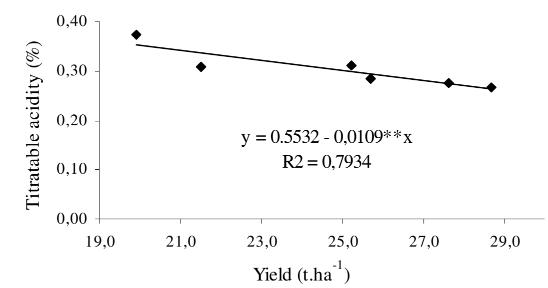

Figure 1D. Linear bivariate regression for Santa Clara TA data (y) as a function of yield (x) of field-grown plants.
Note: ** *P*<0,01

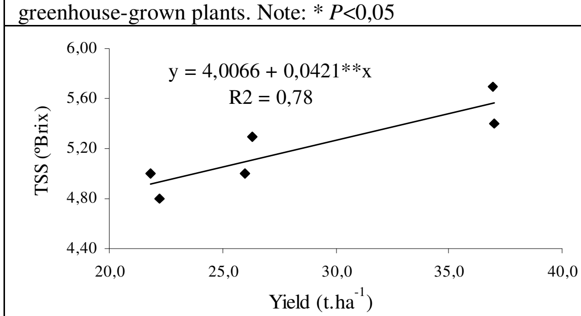

Figure 1E. Linear bivariate regression for Carmem fruit TSS data (y) as a function of yield (x) of field-grown plants. Note: ** *P*<0,01

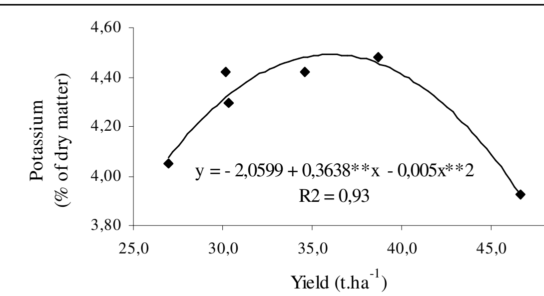

Figure 1F. Linear bivariate regression for BGH-320 potassium data (y) as a function of yield (x) of non-heated greenhouse-grown plants. Note: ** *P*<0,01

Figura 1. The bivariate regression equations (fruit quality vs production characteristic) adjusted for the genotypes Santa Clara and Carmem cultivated in the field.

As with Santa Clara and Carmem fruit TSS:TA ratio, the fruit sugar reducing content of accession BGH-320 produced in a non-heated

greenhouse was affected by plant yield increase. The linear bivariate regression was adjusted for this characteristic (Figure 1C), allowing to conclude that the increase of one unit in plant yield reduced the sugar reducing content by 0.023 unit.

Similar tendency was observed for acidity of Santa Clara fruits produced in the field, whose data were adjusted to the linear bivariate regression model, as a function of plant yield increase (Figure 1D). For this characteristic, the increase in one unit in plant yield reduced titratable acidity of the fruits by 0.01 unit.

TSS of Carmem's fruits produced in the field (Figure 1E) had a behavior similar to those TSS:TA ratio of Santa Clara fruits being adjusted by linear bivariate regression equation. This equation analysis led to conclusion that increase of one unit in plant yield of this genotype increased fruit TSS by 0.04 unit.

For fruit potassium content of accession BGH-320 produced in a non-heated greenhouse, a quadratic bivariate regression equation was adjusted (Figure 1F). This content was found to increase with increased plant yield up to the productivity limit of 36.37 $t.ha^{-1}$, being then reduced with the increase of plant yield.

TSS:TA ratio of Santa Clara fruits and TSS of Carmem fruits produced in the field presented a behavior different from the other characteristics analyzed. The values of these characteristics were found to increase with plant productivity increase.

DISCUSSION

The productivities obtained in this work can be considered low for the genotypes analyzed when compared to commercial productivities of 85.5 $t.ha^{-1}$, obtained by Camargos (1998) with Carmem hybrid and of 162 $t.ha^{-1}$, obtained by Loures (2001) with Santa Clara cultivar, both in non-heated greenhouse; and also of 88.61 $t.ha^{-1}$ obtained by Fayad (2001) with Santa Clara cultivar grown in the field. This fact was due several attack of small tomato borer (*Neoleucinodes elegantalis*) and because it was a summer crop in a region of heavy rainfall.

Except for TSS, values correlating fruit production and quality for the other characteristics evaluated in this work were not found in the literature. The scarce information available in the literature on this subject indicates the existence of a negative correlation between productivity and fruit quality, with latter being referred only to the total soluble solids content (STEVENS; RUDICH, 1978) without specifying other components of fruit dry matter.

The sugar reducing content of fruits from accession BGH-320 and acidity of Santa Clara fruits produced in the field were negatively affected by plant yield increase. Such results can be compared to those described by Stevens and Rudich (1978), who reported, as already mentioned, a negative correlation between plant yield increase and fruit quality. Although no specific reference has been provided by these authors on fruit sugar and acidity contents, except on soluble solids contents, it can be inferred that these results are similar to those reported by them. The basis for such inference is the fact that sugar reducing and acids constitute the majority of the total soluble solids of the tomato fruits (DAVIES; HOBISON, 1981; GRIERSON; KADER, 1986). Thus, a reduction of total soluble solids contents implies a reduction of sugar reducing contents and acidity in the fruits.

Contrary to that observed for the sugar reducing content in fruits of accession BGH-320 produced in non-heated greenhouse and for titratable acidity of Santa Clara fruits produced in the field, TSS:TA ratio of Santa Clara fruits and TSS of Carmem fruits, both field- produced, was positively affected by plant productivity increase. Although this result does not in agree with Stevens and Rudich (1978), it may be valid if one considers the low yield of the plants. Tomato plant is considered to have a limited physiological production capacity, i.e., as yield increases, the plant may not keep the quality of the fruits produced. Beyond a certain limit, which varies as a function of the genotypes and crop conditions, there would be a gain only in yield while fruit quality would be maintained or reduced as a consequence of the physiological capacity of the plant being surpassed. Thus, since plant yield was relatively low if compared to other results previously described, one can infer that these values did not surpass the physiological 'limits' of plant yield in the field, without producing a negative effect on fruit quality.

Stevens and Rudich (1978) attribute an inverse relation between yield and fruit quality to the limited physiological capacity of the plant in furnishing raw material in adequate amount to sustain high yield and fruit quality. According to these authors, the concept of a plant physiological limitation originates from a lack of success in breeding programs. Efforts to enhance the contents of organic acids and sugars in fruits, combined with yield capacity show that increase in one component alters the genetic potential of the plant for this component, although decreasing the potential of the remaining components.

The TSS:TA data adjustment of Carmem's fruits and potassium data of BGH-320's fruits produced in a non-heated greenhouse to the quadratic model of bivariate equation may be related to the fact that higher yields were obtained in this environment. Thus, the physiological limit of the plant was being surpassed. From this point, plant yield increase may be negatively affecting the quality of the fruit being produced, as it has been previously discussed.

CONCLUSIONS

It was concluded that plant yield affect fruit quality. In the field, plant yield increase was followed by TSS:TA increase of Santa Clara fruits and TSS increase of Carmem fruits. However, plant yield increase caused a reduction in the sugar reducing content of BGH-320 fruits produced in a protected environment and in the titratable acidity of Santa Clara fruits produced in the field.

The TSS:TA ratio of Carmem fruit increased with plant yield increase until reaching 78.73 $t.ha^{-1}$. Potassium content of the accession BGH-320 fruits increased with plant yield increase until reaching 36.72 $t.ha^{-1}$.

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RESUMO: O objetivo primordial dos programas de melhoramento é obter variedades de tomateiro capazes de expressar seu potencial máximo de produção sob as mais diversas condições de cultivo. Entretanto, pouca ênfase tem sido dada às características de qualidade dos frutos produzidos. Assim, o objetivo deste trabalho foi avaliar as características de qualidade do fruto SST/AT, açúcares redutores, acidez titulável, sólidos solúveis totais (ºBrix) e potássio em função do aumento da produtividade das plantas. Foram conduzidos dois experimentos no Setor de Olericultura do Departamento de Fitotecnia, na Universidade Federal de Viçosa, Viçosa – MG, de Janeiro a maio de 2002. Utilizou-se o delineamento experimental em blocos casualizados com seis repetições e três genótipos de tomateiro: cultivar Santa Clara, híbrido Carmem, e o acesso BGH-320 do Banco de Germoplasma de Hortaliças da UFV. O experimento em ambiente protegido foi conduzido em casa de vegetação coberta com filme plástico transparente e o experimento de campo sob condições naturais. As características de qualidade do fruto foram alteradas pelo aumento de produtividade das plantas, que reduziu a qualidade dos frutos, exceto para relação SST/AT dos frutos do cultivar Santa Clara e SST dos frutos do cultivar Carmem produzidos no campo, que aumentaram com o aumento da produtividade. O teor de açúcares redutores do genótipo BGH-320 cultivados no ambiente protegido e a acidez dos frutos do cultivar Santa Clara produzidos no campo reduziram com o aumento da produtividade das plantas. A relação SST/AT dos frutos do cultivar Carmem produzidos no ambiente protegido e o teor de potássio dos frutos do genótipo BGH-320 produzidos no ambiente protegido apresentaram comportamento quadrático com o aumento da produtividade das plantas.

PALAVRAS-CHAVE: *Lycopersicon esculentum*. Características qualitativas. Produtividade.

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