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Effect of Arbuscular Mycorrhizae Fungi on the Changes of Physicochemical Composition in Tomato (*Lycopersicon Esculentum*) Fruit

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Abstract

The present work focused on the effect of Arbuscular Mycorrhizae Fungi (AMF) on the changes of physicochemical composition in tomato fruits. Physicochemical composition such as taste index, maturity, moisture, ash, total fibre, protein, glucose, fructose, sucrose, lycopene, total acidity, and mineral nutrients (P, K, Ca, Na) were determined in tomato fruit harvested from pots treated with five Arbuscular Mycorrhizae Fungal (AMF) isolates viz., *Glomus aggregatum, Glomus fasiculatum, Glomus sp, Glomus mosseae, Acaulospora* sp (60 g/pot) in green house condition. There were significant changes in the mean values between the analysed parameters. Glucose and fructose, lycopene and potassium concentrations were strongly and positively correlated. This study reveals that the tomato cultivated with AMF isolates increase the taste, colour, texture and chemical composition. Among all the AMF isolates Glomus mosseae treated tomato yields the best results followed by Acaulospora sp, Glomus sp, Glomus aggregatum and Glomus fasiculatum.

Keywords: *Tomato; Sugar; Lycopene and potassium; Taste index*

Introduction

Tomato (Lycopersicon esculentum) is an annual plant which grows 1-3 m tall in the Solanaceae family. It is one of the most widely consumed fresh vegetables in the industrialized world. It is also widely used by the food industries as a raw material for the production of derived products such as purees or ketchup. It is also the most common vegetable in the Mediterranean diet, a diet known to be beneficial for health, especially with regard to the development of chronic degenerative disease [1]. Tomato fruit quality has been assessed by the content of chemical compounds such as dry matter, Brix degree, acidity, simple sugars, citric and other organic acids and volatile compounds [2]. The ripening of tomato is characterized by the softening of fruit, the degradation of chlorophyll, and synthesis of acids, sugars and lycopene. Tomatoes contain higher level of fructose and glucose than sucrose which evidenced for the sweetness [3,4].

The use of AM inocula in agriculture is relatively recent; their efficacy can be influenced by the modality of application to soil and by the crop [5]. Mycorrhizae are symbiotic relations with fungi and plant roots and are known to be beneficial for both plants and fungi, as the AM fungi obtain photosynthesis carbon from the plant and in turn provide inorganic nutrients to the plants [6].

In general, plant roots inoculated with AMF are more efficient in nutrient and water attainment, thus causing an improved plant growth, compared with non-inoculated plant roots [7]. For the impact of AMF on growth, production and water use efficiency of some vegetable crops such as watermelon, tomato and onion plants with AMF promote plants growth, enhance fruits and bulbs yield, respectively as well as improve water use efficiency under well watered and water stress conditions. [7-10].

The aim of this paper is to determine the physico-chemical composition of tomatoes produced from various treatments with AMF isolates.

Materials and Methods

Crop study with Arbuscular Mycorrhizal Fungi isolates

Certified seeds of Tomato used in this study were collected from Horticulture College and Research Institute, Periyakulam, Theni District, Tamil Nadu, India. The seeds were treated with 0.5% sodium hypochlorite for 15 min and 10 undamaged seeds were sown in plastic pots containing 2.8 kg soil. Five mycorrhizal inoculums viz Glomus aggregatum (T1), Glomus fasiculatum (T2), Glomus sp (T3), Glomus mosseae (T4), Acaulospora sp (T5) [11] were inoculated in the pots and maintained triplicates along with a control (T0). Each pot received 60 g mycorrhizal inoculum as a layer of 0.5 cm thickness, 5 cm below the seeds. Control pots (non-mycorrhizal) filled with soil alone. Two weeks after sowing, tomato plants were thinned to 5 plants per pot. All the pots were maintained for the total growth period of 85 days in green house condition [12].

The tomatoes were harvested during October 2013 and they were selected at point 7-8 of the ripening chart (Kleur - stadia tomaten, Holland). Tomatoes were randomly selected from each treatment and the tomato fruit in control were also taken for analysis.

Analysis of physicochemical composition in tomato fruit

Ripened tomato fruits selected for the physicochemical analysis were rinsed with ultrapure water and dried with blotting paper and then the tomatoes were homogenized to a homogenous puree using mortar and pestle. The homogenized tomato sample were analysed for various physicochemical parameters such as moisture, total dry matter, ash, protein, total soluble sugars(TSS), total acidity, total fibre, taste index , phosphorus (P), potassium (K), calcium (Ca), sodium (Na) and lycopene, followed by the standard methods.

Taste index and tomato fruit maturity were determined by the following formula: and

$$Taste\ index = \frac{Brix\ degree}{20\ X\ acidity} + acidity\ \ Navezet.,\ al.(1999)$$

$$Maturity = \frac{Brix\ degree}{acidity}\quad Nielson(2003)$$

The moisture content of tomato fruit was determined by dessication at 105°C for 24 hrs [13]. Ash was determined by calcinations at 550°C for 24 hrs, for the residue obtained in the moisture determination [13]. Total fibre was determined by the method proposed by Sky. The determination of sugars [14] was performed spectrometrically; lycopene [15] and the estimations of P, K, Na and Ca were carried out with flame photometer (Systronic 129 μc) Shah., *et al*. [16].

Statistical analysis

Statistical analysis for various physicochemical parameters analysed in tomato fruit was performed by Graph pad Prism 6 software for windows. Mean values were compared by One - Way ANOVA, Simple Linear regression was used to indicate a measure of the correlation and the strength of the relationship between two variables. The graphical representations in the research work were carried out by using Origin 6.0 software for windows.

Results and Discussion

The results obtained for various physicochemical parameters analysed in tomato fruit samples from treatments using five different AMF isolates viz Glomus aggregatum, Glomus fasiculatum, Glomus sp, Glomus mosseae, Acaulospora sp and in the control (without AMF) are shown in Table 1 and Figures 1 (a to d), 2, 3. Significant differences were observed between the values obtained for all the parameters. Tomato fruit harvested from the treatment with Glomus mosseae (T4) showed the highest values for all the physicochemical parameters. These findings agree with the recent studies of Oseni., *et al*. [7]; Guru., *et al*. [9], Tanwar and Castillo., *et al*. [17], in tomato plants treated with AMF isolates.

This positive effect might refer to the role of AMF in enhancing uptake of nutrients and successive water relation which led to better growth and larger plant size [18]. The improvement of vegetative growth of tomato plants may be attributed to the appropriate balance of moisture in plants, which creates good conditions for nutrients uptake, photosynthesis and metabolites translocation, which in final led to speed up the rate of vegetative growth [19].

Parameter			Treatments				P value	Significance
	T0	T1	T2	T3	T4	T5		
Weight (g)	102 ± 26.3	91.1 ± 23.7	107 ± 25.5	111 ± 28.9	119 ± 30.3	91.9 ± 13.1	0.000	***
Moisture	93.9 ± 0.8	93.8 ± 0.9	93.8 ± 0.8	93.9 ± 0.9	94.0 ± 0.8	94.1 ± 0.6	0.383	***
Ash (%)	0.62 ± 0.07	0.59 ± 0.08	0.61 ± 0.06	0.63 ± 0.08	0.65 ± 0.06	0.61 ± 0.06	0.001	***
Total fibre (%)	1.82 ± 0.53	1.87 ± 0.46	1.84 ± 0.49	1.74 ± 0.65	1.92 ± 0.66	1.71 ± 0.48	0.447	***
Protein (%)	0.80 ± 0.15	0.79 ± 0.16	0.78 ± 0.13	0.82 ± 0.15	0.87 ± 0.12	0.78 ± 0.16	0.158	
Glucose (%)	0.93 ± 0.40	0.85 ± 0.28	1.00 ± 0.40	0.91 ± 0.51	1.16 ± 0.49	0.86 ± 0.37	0.037	****
Fructose (%)	1.02 ± 0.41	0.96 ± 0.28	1.04 ± 0.41	0.97 ± 0.47	1.21 ± 0.54	0.98 ± 0.40	0.109	****
Sodium (%)	1.33 ± 0.01	1.67 ± 0.06	1.33 ± 0.42	1.44 ± 0.64	1.75 ± 0.72	1.50 ± 0.04	0.001	ns
Calcium (%)	6.24 ± 1.2	8.61 ± 1.57	7.09 ± 1.72	6.54 ± 0.93	7.88 ± 2.34	7.22 ± 0.87	0.327	ns
Potassium (%)	4.10 ± 1.25	4.11 ± 1.20	3.6 ± 0.79	4.7 ± 0.92	4.7 ± 0.89	4.1 ± 1.23	0.000	****
Phosphorus (%)	3.39 ± 0.72	3.93 ± 0.77	3.40 ± 0.42	3.44 ± 0.37	4.58 ± 0.42	4.30 ± 0.4	0.222	ns
Lycopene (%)	6.0 ± 1.2	7.1 ± 1.83	7.4 ± 1.62	7.0 ± 1.72	7.4 ± 2.10	5.5 ± 1.7	0.231	****
Dry matter	5.1 ± 0.21	5.6 ± 0.13	5.8 ± 0.42	5.7 ± 0.44	6.5 ± 0.36	5.4 ± 0.42	0.027	ns
Taste index	0.97 ± 0.09	0.94 ± 0.08	0.98 ± 0.10	0.97 ± 0.10	1.00 ± 0.07	1.00 ± 0.07	0.041	****
Maturity	9.4 ± 1.9	9.3 ± 1.9	9.0 ± 1.8	9.5 ± 1.8	9.7 ± 2.0	9.7 ± 1.7	0.411	***

***Table 1:** One way ANOVA for the changes in physicochemical composition of tomato fruit produced from various treatments by using AMF isolates.*

All the values are triplicates of mean and standard deviation; ns- non significant,
*****-significant at 0.0001% level (strongly significant),*
****- significant at 0.001% level (extremely significant).*
T0 = Sand + Red soil (1:1) control; T1 = Sand + Red soil (1:1) + Glomus aggregatum (60 g/pot)
T2 = Sand + Red soil (1:1) + Glomus fasiculatum (60g/pot); T3 = Sand + Red soil (1:1) + Glomus sp (60 g/pot); T4 = Sand + Red soil (1:1) + Glomus mosseae (60 g/pot); T5 = Sand + Red soil (1:1) + Acaulospora sp (60 g/pot).

The mean percentages of all the parameters analysed in tomato fruit produced from various treatments with AMF isolates infers the results in the following sequence viz., Glomus mosseae > Acaulospora sp > Glomus sp > Glomus aggregatum > Glomus fasiculatum > control. The sequential results may be due to the improved root development and transport of nutrients as reported by Berta., *et al*. [20].

Figure 1 a to d showed the concentration of weight (119 ± 30.3), moisture (94.0 ± 0.8) was in the usual range on par with the experimental results of by Li., *et al*. [21]. The mean ash content (0.65 ± 0.06) was similar to the results of Oke., *et al*. [22]. The total fibre in the analysed tomato samples treated with AMF isolate was 1.92 ± 0.66 which was higher than the other data found in the literatures of Moreiras et al. Anta., *et al*. [23]. The protein content (0.87 ± 0.12), the content of glucose (1.16 ± 0.49) and fructose (1.21 ± 0.54) Sodium (1.75 ± 0.72), potassium (4.7 ± 0.89), calcium (7.88 ± 2.34), phosphorus (4.58 ± 0.42), lycopene (7.4 ± 2.10), dry matter (6.5 ± 0.36), and maturity (9.7 ± 2.0) obtained was similar to the data found in some food composition charts and data's described in the literature of Wheeler and Berry [24].

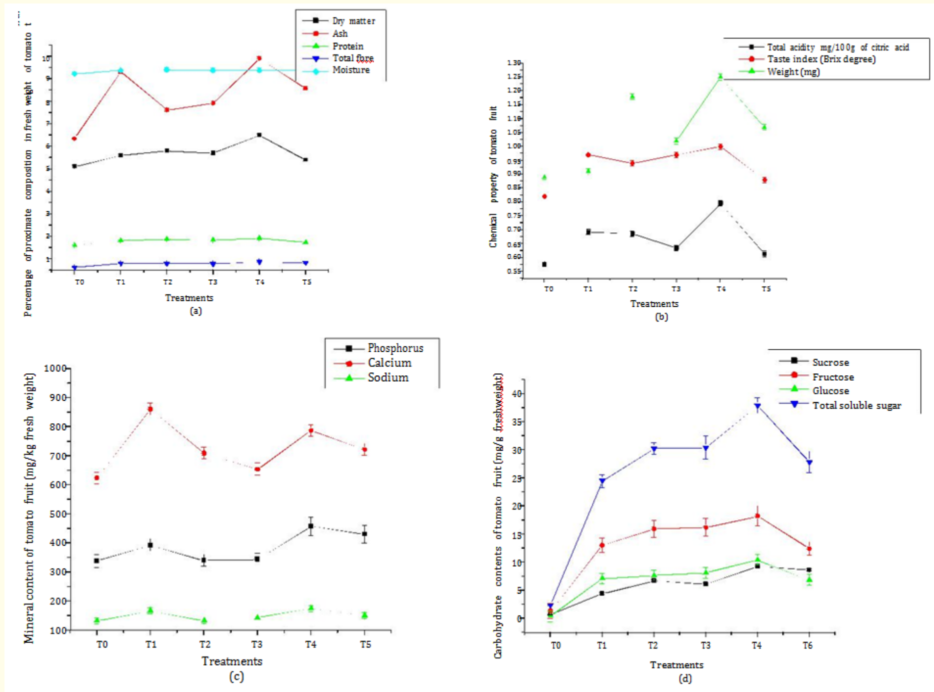

***Figure 1:** Changes in Physico chemical composition of tomatoes produced from various treatments by using AMF isolates.*

T0 = Sand + Red soil (1:1) control;

T1= Sand + Red soil (1:1) + Glomus aggregatum (60g/pot)

T2= Sand + Red soil (1:1) + Glomus fasiculatum (60g/pot);

T3 = Sand + Red soil (1:1) + Glomus sp (60g/pot);

T4 = Sand + Red soil (1:1) + Glomus mosseae (60g/pot); T5= Sand + Red soil (1:1) + Acaulospora sp (60g/pot).

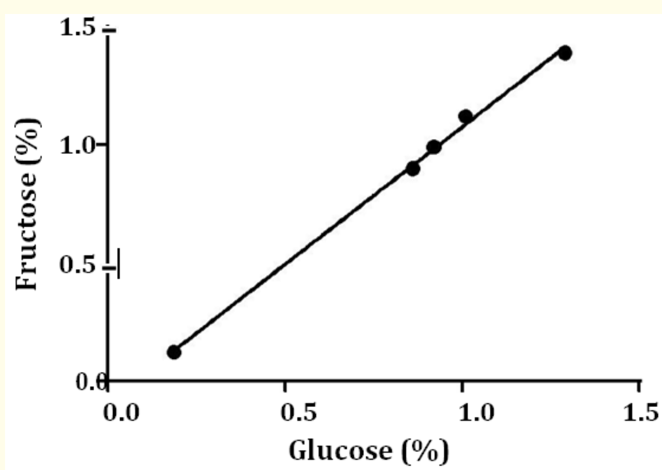

***Figure 2:** Correlation between Fructose and Glucose in tomato.*

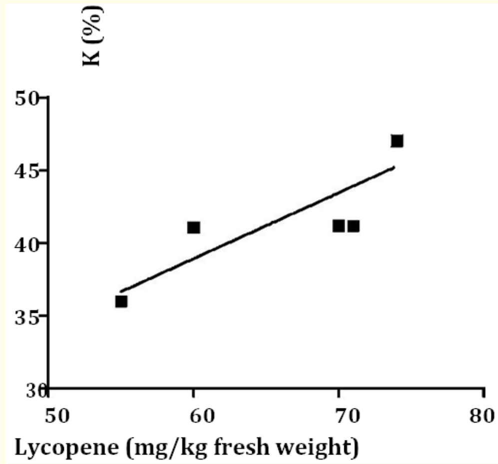

Figure 3: *Correlation between Potassium and Lycopene in tomato.*

Taste index is calculated using the values of Brix degree (6.90 ± 0.09) and total acidity (1.00 ± 0.01 g/100g of citric acid), obtained by the formula reported by Navez., *et al*. [25]. When using these data, the mean values of the taste index in all the AMF treated tomato were higher than 0.85% which indicates that the tomato fruit produced from various treatments with AMF isolates is tasty. Navez., *et al*. reported that the value of taste index lower than 0.7, the tomato is considered are having little taste. The weight and total fibre were highly significant in the tomato inoculated with Glomus mosseae than other treatments.

Inoculation of AMF to tomato crops resulted in significant increment in titratable acidity, and total sugars contents compared to their respective plants in control without AMF. These results agreed with the findings of Sirichaiwetchakul., *et al*. [26] who indicated that AMF species G. mosseae improved fruit quality of cherry tomato grown under glasshouse conditions by increasing ascorbic acid and Total Soluble Sugars (TSS). Increased TSS content in tomato fruits with increasing water stress was also detected in other studies [27].

Liu., *et al*. [28] reported the positive effect of mineral uptake by mycorrhiza which is evident in the present study with the increased mineral uptake in the AMF inoculated tomatoes than control. The superior fruit yield advantage exhibited in AMF treated plants result from enhanced uptake of mineral nutrients from soil, chiefly immobile ions like P (1626 ± 226), K (1800 ± 139), Ca (162 ± 3) and Na (185 ± 36) mg/kg fresh weight of tomato fruit and improve nutrient translocation system, result in increased biomass. [9, 29].

The level of P may also influence the reproductive efficiency by improving pollen performance. Thus, according to Poulton., *et al*. [30] mycorrhizal infection are capable of increasing pollen quality (*in vitro* and *in vivo* pollen performance) as well as pollen quantity.

Fanasca., *et al*. [33] described that a high proportion of K in the sample increased quality attributes such as lycopene content, this may have played a role to increase lycopene content in the present study. AMF-application showed increased contents of carotenoid and total phenolic in turn lycopene content. Similar results were reported by Taiz and Zeiger [34].

The enhancement of water and soil nutrient uptake through AMF inoculation can enhance photosynthetic performance [35], which in turn triggers an increase in synthesis of carotenoid pigments. Carotenoids, which serve as accessory pigments in photosynthesis and also as photo protective agents, are isoprenoid (terpenoid) compounds, which originate in the primary carbon metabolism [34].

The results of present work showed that the fructose content of tomato fruit is higher than the glucose these results are in confirmatory with the earlier studies by several researchers [36,37]. Moreover, growing environmental factors and many other factors influence tomato fruit taste. Sweetness is particularly appreciated in tomatoes for industrial use, and is usually correlated with fructose and glucose content mainly accumulated into the vacuole of fruit cells [38].

The concentration of glucose and fructose reported in the present study was similar to the reports of Loiudice., *et al*. [39] and Osvald., *et al*. [40]. The concentration of tomato carbohydrates ranged between 3% and 5% according to the food composition charts reported by Moreiras, Ortega Anta., *et al.* [23].

According to the statistical analysis (Figure 2 and 3) there was possible correlation between glucose & fructose and potassium & lycopene (r = 0.854, and r = 0.998). The similar correlation was observed in other fruits such as banana by Rodriguez and Diaz [41]. This may be due to the common origin for the sugar which is obtained from sucrose hydrolysis [42-52].

Conclusion

A significant impact of globalization on horticulture has been an increasing demand for quality improvement. Tomato (Lycopersicon esculentum) is a major horticultural crop with an estimated global production of over 120 million metric tons (F.A.O. 2007). Tomatoes must have a flavour, colour and texture that satisfy the consumer's preference. In the European Union (E.U.), the application of quality standards to fresh tomatoes has increased the uniformity in size, maturity and presentation of produce. However, the most significant quality characteristic of a product serves with flavour and aroma. Hence the present research work with tomato treated with Glomus mosseae and other AMF isolates satisfy the European Union standards with the increased nutrient content, taste, colour, texture, flavour and aroma.

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