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Short Research Article

Tomato Fruit Quality under Protected Environment and Open Field Conditions

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Abstract

Vegetables are important component of balanced human diet. Advanced production technologies are being followed to measure productivity and quality of produce. Protected cultivation is an improved agro technique being used worldwide to register 3-4 times increase in production. Tomato is grown extensively in the plastic greenhouses for higher productivity. The growing conditions especially light and temperature are known to influence both composition and quality of tomato fruits. Hence, studies have been conducted to estimate the quality parameters of tomato grown both under open and in polyhouse with shade nets during cloudy weather in rainy season The results reveals that the fruits harvested from the field had higher TSS:TA ratio (11.73), acidity (0.49%), total sugar (2.5%), ascorbic acid (14.7 mg $100g^{-1}$), TSS ($5.76^{o}B$) and the lycopene content (8.7mg 100 g^{-1}) than the fruits grown under protected conditions. However, the environment in the polyhouse favour the growth and development of tomato plant through increased plant height (1.4m) and number of branches. The fruit yield obtained from the polyhouse was higher (2.6 kg $plant^{-1}$) than the open field (1.5 kg $plant^{-1}$). Hence, both types of environmental conditions are favourable in some aspects. The parameters of economic importance like fruit weight and yield are better under protected conditions but the nutritional parameters like vitamin C and lycopene content are higher in open conditions during rainy season.

1. Introduction

Vegetables are considered as health food because of their nutritional awareness among people. Hence major emphasis is being given to improve the quality of produce along with higher production. Apart from genetic potential of a variety the other components which influence productivity and quality of vegetable are growing environment and agro techniques. This vegetable is rich source of vitamins and antioxidants like lycopene.

In hilly regions, it is grown for off season produce especially during rainy season. Nowadays it is grown both under open field conditions and protected structures with shade nets installed for cooling. Since weather is mostly cloudy during rainy season so there is an urgent need to determine the various constituents of nutritional quality in tomato grown in open and under reduced light regime in polyhouses.

Tomato fruit contains high moisture and dry matter (DM) of 5-7.5% (Davies and Hobson, 1981). The composition of dry matter in tomato consists of sugars, mainly glucose and fructose, organic acids (citric and malic acid); minerals, (N, P and K) , vitamins and anti-oxidant pigments such as lycopene. Besides its importance for consumption, fruit acidity and total soluble solid content are vital factors in the processing industry. The acidity is related to pH and low pH of the pulp prevents the growth of microorganisms that are harmful (Carvalho, 1980), which in turn decreases the period of heating needed for sterilisation during processing (Stevens, 1972). However, the total soluble solids content (TSS) is important especially when the objective is dehydration, concentrated pulp preparation, or both (Stevens, 1972). Lycopene, ascorbic acid (Vitamin C) and potassium contents are important for the nutritional value of tomatoes; they have beneficial effects on human health. Franceschi et al. (1994) and Frusciante et al. (2000) reported that the consumption of the tomato and its products (i.e., ketchup, paste) is negatively correlated with the development of tumours in the digestive tract and prostate cancer. Vitamin C plays an important role in human health and it is found in fruits and vegetables in the form of ascorbic acid. Its main functions are in the prevention of scurvy and maintenance of skin and blood vessels (Lee and Kader, 2000). The dry matter composition of a tomato, vitamin C, lycopene and potassium contents varies mainly with the genotype. Orange-coloured tomato cultivars have high contents of carotenoids and volatile compounds, while yellow fruit cultivars have a lycopene content ten-fold lower than red coloured fruit cultivars (Hart and Scott, 1995). Wild species may have twice as much lycopene and Vitamin C than the commercial cultivars (Dorais et al., 2001). Besides being influenced by genotype, some fruit constituents are also affected by environmental conditions. For example, vitamin C and lycopene contents are strongly affected by light intensity and temperature as reported by Venter (1977), Chang et al. (1977) and Davies and Hobson (1981).

In traditional vegetable-producing regions, tomato cultivation in a protected environment has expanded to make the fruits available in the off season. Alterations in light intensity, temperature and relative humidity occur in protected environments and can affect production and the partitioning of photo-assimilates in the plant, consequently, the composition of the produced fruit (Martinez, 1994; Bakker, 1995).Hence the present studies have been aimed to evaluate the effect of different cultivation environments on quality characteristics of tomato, especially when grown in the low cost naturally ventilated polyhouse with shade nets.

2. Materials and Methods

2.1. Raising of crop

Two experiments were carried out, one in a protected environment (naturally ventilated polyhouse) and the other in an open field at the Vegetable research farm, Department of Vegetable Sciences, Dr YS Parmar University of Horticulture and forestry, Nauni, HP, India. The experiments were arranged in a randomised complete block design, with six replications of Naveen 2000$^+$ genotypes, which is recommended for cultivation under protected and open field environments. The protected environment experiment was conducted in polyhouse (6 m wide, 32 m long and 4.5 m high) with retractable lateral shades (25%) and a plastic film cover. The field experiment was conducted under natural conditions, without any protection. The seedlings were produced in trays (128 cells) and 20 days old seedlings were transplanted into the soil of both environments. Drip irrigation and weekly fertigations were applied throughout the growing season in both experiments, with 250 kg NPK ha^{-1} through water soluble fertilizer (Polyhouse) having 19: 19: 19 NPK to polyhouse and 120 kg N ha^{-1}, 60 Kg P ha^{-1} and 80 Kg K ha^{-1} in open field through straight fertilizers. Standard cultivation practices were followed to grow the crop and harvesting was done when fruits reached the completely ripe stage (80% of their surface attaining red colouration).

2.2. Physico-chemical analysis

Eight fruits per replication in both the experiment were harvested and homogenised forming one composed sample for quality analysis. Titratable acidity (TA), was determined by titration of the homogenized sample with 0.01N NaOH (expressed as % citric acid) and pH, determined in 50 g samples of pulp with a digital pH-meter. Total soluble solids (TSS) determined with a digital refractometer and TSS TA^{-1} ratio a flavour indicator as described by Kader et al. (1978). Reducing and total sugar content estimated by applying the method of Dubois et al. (1956) modified by Sawhney and Singh (2000). Total carotenoids, expressed as "lycopene", was estimated using spectrophotometry (Thimmaiah, 2006). Ascorbic acid content, determined by titration with 2, 6-dichlorophenolindophenol, according to the AOAC (1975).

2.3. Statistical analysis

Mean values were compared by Fischer's T test ($p \leq 0.05$), using the Statistical and Genetic Analysis System (SAEG).

3. Results and Discussion

A significant effect of crop environments was verified by the traits viz., Plant height, yield, titratable acidity, total soluble solids, TSS:TA ratio, total and reducing sugar content, lycopene and ascorbic acid, while pH was not influenced by crop environment. The plant height (140 cm) of the crop grown under protected condition was more in comparison to the field grown (90 cm) crop. The tomato plants grown in polyhouse climate produced about 50% higher fruit yield (90 t ha^{-1}) than the tomato plants grown in open field conditions (54 t ha^{-1}). The significantly higher yield in the plants grown under polyhouse condition over the plants grown in the open field was associated with the production of higher number of fruits (38) with greater length (4.4 cm) and diameter (5.4 cm) and fruit weight (68 g) than those in open field (Table 1). These results are in agreement with Kang and Sidhu (2005) and Parvej et al. (2010).

The data presented in Table 2 revealed that fruits produced in open field were more acidic (0.49%) than fruits produced in a protected environment (0.40%). The environmental effect on fruit acidity is complex and some studies favour the hypothesis that organic acids are produced in the fruit itself from stored carbohydrates (Sakiyama and Stevens,1976), although some of these acids may be translocated from the leaves and roots to the fruits (Bertin et al., 2000). Thus, the lower acidity of the

Table 1: Growth and yield characteristics of tomato plant grown under polyhouse and open field conditions

Climate	Plant height (cm)	Number of fruits plant^{-1}	Fruit length (cm)	Fruit diameter (cm)	Fruit weight (g)	Yield (kg pl^{-1})	Fruit yield (t ha^{-1})
Open field	90^{a}	24^{a}	3.8^{a}	4.9^{a}	68^{a}	1.5^{a}	54^{a}
Protected	140^{b}	35^{b}	4.4^{b}	5.4^{b}	75^{b}	2.6^{b}	90^{b}

Similar letter with in a column do not differ significantly by Fischer T-test ($p \leq 0.05$)

Table 2: Fruit quality characteristic of the tomato hybrid grown in different environments

Cultivation Condition	Quality characteristics
	Titratable acidity (% citric acid)
Protected	0.41^{a}
Open field	0.49^{b}
	pH
Protected	4.48^{a}
Open field	4.49^{a}
	TSS °B
Protected	3.71^{a}
Open field	5.76^{b}
	TSS:TA
Protected	9.23a
Open field	11.73b
	Total Sugars (g 100 g^{-1})
Protected	4.15^{a}
Open field	5.30^{b}
	Reducing Sugar (g 100 g^{-1})
Protected	1.92^{a}
Open field	2.50^{b}

Similar letter with in a column do not differ significantly by Fischer T-test ($p \leq 0.05$)

fruits grown in the protected environment may be a result of the lower photosynthetic activity of the plant (shading in protected environment) in this environment and lower carbohydrate accumulation in the fruits during summer season. Similarly, Loures (2001), evaluating the tomato hybrid 'Carmem' and found fruit titratable acidity (citric acid) of 0.46% and 0.49% under polyhouse and field conditions, respectively. The low values of titratable acidity were because of red tomato fruits used for analysis.

The TSS content observed in fruits analysed in this work were higher in open field (5.76°B) than the protected condition (3.71°B). In contrary to above results Loures (2001) found a TSS content of 4.77 °B and 4.95 °B for 'Carmem', grown in the field and in a protected environment, respectively. Tomato TSS is due to the reducing sugar (Ho and Hewitt, 1986), thus, any factor that alters sucrose synthesis (photosynthetic activity) will affect glucose and fructose accumulation in the fruits, thus altering TSS. Tomato had a good flavour when presenting a TSS:TA ratio of 10 (Kader et al., 1978). The hybrid evaluated here had TSS: TA ratios of 11.73 in open field in comparison to protected i.e. 9.25, thus being adequate for fresh consumption.

The reducing sugar contents of tomato fruits produced in the field had higher contents (2.5g 100 g^{-1}) than fruits produced in the protected environment (1.92 g 100 g^{-1}). Beckmann et al. (2006) explained as high sugar content in the fruits produced in the field may be due to the greater light intensity and greater photosynthetic plant activity in this crop environment. The reducing sugar content in the appraised fruits is in agreement with the results Davies and Hobson (1981).

Field-produced tomato fruits were expected to show a higher lycopene content than fruits produced in a protected environment since, under favourable temperatures (22-25ºC), lycopene biosynthesis is stimulated by luminosity, which was approximately 25% more intense in the open field. In the present experiment there was no significant variation in lycopene content under both the cultivation conditions. Genotype influenced the "lycopene" content of fruit, while the environment did not influence this characteristic (Figure 1). However, "lycopene" contents in the fruits of the evaluated hybrid were in agreement with the values presented by Frusciante et al. (2000). Significantly high ascorbic acid was found in open field (14.50 mg 100 g^{-1}) than the fruits grown in

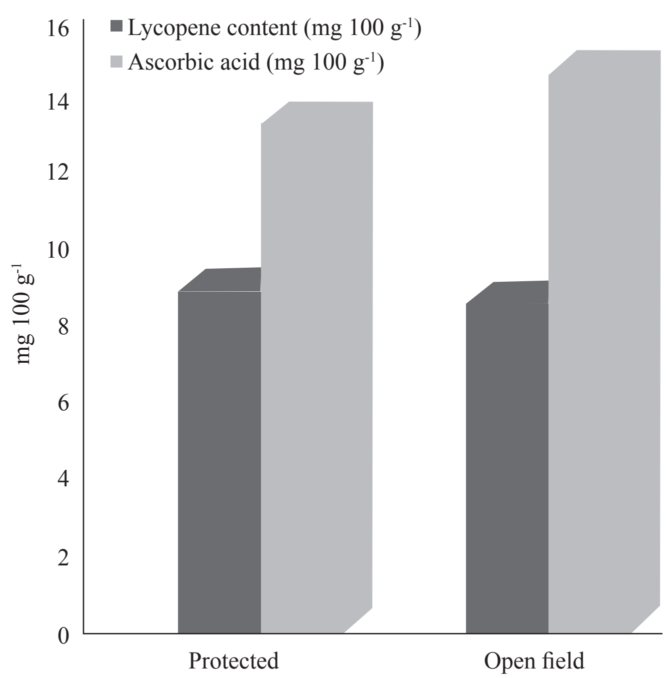

Figure 1: Antioxidant compounds in tomato under open and polyhouse environment

polyhouse (12.82 mg 100 g^{-1}). Ascorbic acid biosynthesis can be strongly influenced by environmental cultivation conditions, with light intensity affecting the content of ascorbic acid in tomato fruits (Venter, 1977). Besides climatic conditions, the genotype has a great effect on ascorbic acid content in tomato. The ascorbic acid contents of the fruits analyzed in this work are in agreement with Davies and Hobson (1981), who reported a variation between 10 and 30 mg of ascorbic acid 100g^{-1} of fresh fruit in protected environment and in open field. Similarly, Loures (2001) obtained 4.80 mg and 5.65 mg ascorbic acid 100g^{-1} of fresh weight of 'Carmem' fruits produced in a greenhouse and in the field, respectively. Despite not being essential for ascorbic acid synthesis, luminosity may affect its accumulation during the growth of the plant and fruit. Ascorbic acid is synthesized from photosynthesis-produced sugars (Lee and Kader, 2000). As previously mentioned, sugar production is a function of the plant's photosynthetic rate, which, in turn, is a function of luminosity intensity. Thus, a lower ascorbic acid content of the fruits produced in a protected environment is probably caused by the lower luminosity in this environment, which may have reduced the production of sugar, a substrate that is used in the synthesis of ascorbic acid.

Besides the difference in light intensity and other climatic factors in the protected environment were around 10% higher than those in the field. High relative air humidity can reduce plant transpiration and promote xylematic flux of water, which is favourable to the fruits, since the fruits act as drains for high concentrations of organic molecules and, consequently, low water potential (Bertin et al., 2000). Thus, absorption of water by the fruits may have been favoured in the protected environment and, consequently, may have led to a "dilution effect", causing the fruits grown in the protected environment to be less flavourful and have lower contents of soluble solids, reducing sugar and ascorbic acid contents than the fruits grown in the field.

4. Conclusion

In a general, the yield and other physical parameters of the tomato were higher in polyhouse than the fruits grown in open field condition during summer season. However, fruits produced in the field presented better quality like TSS, lycopene content, ascorbic acid than that fruits produced in shaded protected environment during rainy season. Field-grown fruits were more palatable due to the high TSS:TA ratio. Therefore, it may be concluded that shade nets may be avoided on the protected structures during rainy season especially in the hilly regions where weather remains cloudy, to improve the quality of the fruit in addition to the yield. However, more studies are required to see the effects of shade nets during other seasons.

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