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Improvement of Sensory Attributes of Tomatoes (*Lycopersicon esculantum* Mill) Through Hydroponics

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ABSTRACT

A trial was conducted in the unheated glasshouse to find the possible influence on important sensory features of tomato considering the various organic and inorganic substrates mostly used in soilless culture (Hydroponics), in comparison with the border soil. It was noticed that most of the seedling and planting media main effects including their combinations had a significant impact on all the parameters under consideration. Border soil or the soil mixture developed early fruit colour than perlite. Fruits from grapes marc or straw bale or their combinations with soil-based compost or peat compost due to more protopectin had high fruit firmness in comparison with the fruits taken from perlite and / or border soil. Highly flavored fruits had already proved to have less water contents containing more dry matter and / or TSS contents, thus, seedling derived from soil-based compost when grown into straw bale and / or border soil resulted in the production of high flavor whereas grapes marc could not show good performance. The general acceptance for good taste of tomatoes is determined by sugar-acid ratio and such fruits are usually less watery, relatively higher in dry matter and TSS contents with good flavor.

Key Words: Soilless technique; Hydroponics; Bags culture; Tomato; *Lycopersicon esculentum* Mill

INTRODUCTION

The various methods and techniques developed for growing plants without soil are collectively called hydroponics or soilless culture. The methods of soilless culture include diverse system, from the purely culture based on water and nutrients only (e.g., nutrient film techniques or NFT), to those based on artificial mixes that contain various properties of soil (Butt & Varis, 1999). Between these extremes lie a great number of soilless methods that makes use of some sort of growing medium, either inert (e.g., perlite, rockwool) or not inert (e.g., gravel culture, sand culture and peat bag culture). The method of bag culture in soilless technique has now taken an advanced shape many parts of the world (Butt & Varis, 2000; Butt, 2002). Literature has indicated that different growing media contributed a lot in improving the tomato fruit quality particularly with respect to their sensory traits which are influenced by several interacting factors and genetic background of a variety has a profound effect of all these aspects. In the European countries like UK, consumers are exigent to the quality and appearance of fresh tomato and do pay a premium price for tomato fruits. Some quality defects in the commercial production of tomato may be improved by cultural management and by using the various growing media (Day, 1988; Del-Carmen-Salas *et al*., 1998). Good external quality includes uniform size, shape and colour, with firm flesh. A good taste results from a pleasing combination of both texture and flavour. Texture is related to wall thickness and firmness whereas flavour is determined by the balance of sugar, free acids and numerous volatile organic compounds, which are present in only trace amounts (Day, 1988). Refinements to high intensity growing techniques continue to increase yield, but the major emphasis is still on visual quality. The uptake of crop nutrients for any cultivar of tomato can be manipulated to promote taste and flavour components. For instance, acidity in ripening tomato fruit normally reaches a peak prior to full colour development, malic acid decreases in concentration and is replaced by citric acid. The colour of tomato fruits is very useful for fruit quality inspection because it is the main factor of the consumer acceptance during purchase. Red tomatoes contain the pigment, lycopene. As the fruit approaches to ripening stage, the contents of lycopene and other coloured carotenes including β-carotene are progressively increased, thus, the fruit turns red in colour. The colour values of red tomatoes were found highly correlated with lycopene contents. The same result appeared between colour value and total amount of coloured carotenes (including lycopene, β-carotene and all other minor coloured carotenes) (Johjima & Matsuzoe, 1995b).

For optimum plant performance to get the consequent quality tomato fruits including their sensory features, the root system has to be able to develop well and find itself in favorable surroundings. This is because the growth and development of a plant is in direct correlation with the composition of a growing media. Little knowledge is available on the suitability of root environment and how these could be created in a specific artificial substrate including various soil-based composts for tomato crop. The possible way could be coupled with the parameters measured in tomato plants that are grown in the chosen growing media. By developing the standardized growing techniques through close system of production, the sources can be taken into account for best utilization. Thus the main objective of this study was to ascertain the possible suitability of growing media for quality seedlings (transplants) production and, in turn, producing high quality tomatoes.

MATERIALS AND METHODS

The experiment was conducted in the unheated glasshouse by selecting beefsteak tomato cultivar, *Correct F1* which has high yielding and good fruit size of acceptable sensory qualities. The seedlings were sown at the advent of spring and harvested before the start of monsoon season. Three Seedling media (SM) namely Soil-based compost (SBC), Perlite (PER) and Peat compost (PC), while five Planting media (PM) namely Soil-based compost (SBC), Perlite (PER), Straw bales (SB), Grapes marc (GM) and Border soil (BS) along with their 15 different combinations were used in the experiment.

Seeds were sown in the plastic trays filled with three seedling media and kept in the incubator for optimum germination. The 15 days old seedlings were transplanted in 500 ml black polyethylene bags. Each bag of perlite was given cuts to its sides for making individual reservoir and all perlite bags were kept on the surface of a table filled with nutrient feed. The bags of peat and soil-based compost were watered and/or fed with feed from the top of the bags. The ready transplants were planted in 10 L bags filled with perlite planting media and soil-based compost and grapes marc in 15 L bags. The planted bags of perlite were made reservoir by giving four horizontal slits at the height of 5 cm above the bag whereas in case of grapes marc, low-height reservoir (3.0 cm) was made with two horizontal slits of 5 cm length each on both sides of the bag were made to facilitate 20% run off. However, the bags of soil-based compost were given 2 slits of 5 cm each at the bottom. Well fermented straw bales (20 kg each) were rowed for planting the ready transplants derived from three seedling media. In border soil, the plantation was done on flat beds of 100 cm wide and P x P was maintained 50 cm.

The chemical composition of grapes marc is strongly related to the origin of material and its composition evaluated was, pH 4.5–5.5; N-NO_3 40–50 ppm; phosphorous 0.2–0.1 ppm and potassium 250–300 ppm. In the early stage of seedling development, grapes marc, soil-based compost and straw bale were fed with (mg/L) 119 N, 60 P_2O_5 and 340 K_2O at every watering which later on, increased to 115 N, 25 P_2O_5 230 K_2O and 15 Mg (Butt & Varis, 1996) The plants grown in the border soil were given the fertilizers in split doses @ 8g N and 17g K_2O per meter square. However, the plants grown in perlite were provided continuous feed and the quantity of elements contained were 123 N, 41 P, 186 K, 125Ca,18 Mg, 57 S, 1.5 Fe, 0.7 Mn, 0.4 B, 0.2Cu, 0.2 Zn and 0.05 Mo. Electrical conductivity and pH of the feed were maintained with the values of 1700 μS/cm and 5.8, respectively.

A panel of 10 judges was constituted and the mean values of each parameter were calculated on the mean of the scores of 10 judges. The studied sensory parameters were; fruit colour, fruit firmness, fruit flavour and general likeness of fruit. The characteristics of these parameters were evaluated by using 5-point scale (Dethmers, 1981) given as below:

Colour	Point	Flavor	Point
Dark red	5	Very good	5
Red	4	Good	4
Light red	3	Fair	3
Pink red	2	Bad	2
Light pink	1	Very bad	1
Firmness	**Point**	**General likeness**	**Point**
Very hard	5	Very much liked	5
Hard	4	Liked	4
Less hard	3	Acceptable	3
Soft	2	Less liked	2
Very soft	1	Disliked	1

The data of all these parameters were statistically analyzed by adopting one factor- Randomized Complete Block Design (RCBD) for seedlings and two factor factorial with RCBD arrangement for 15 interactions of seedling and planting media, to get the Analysis of Variance by using Michigan M-STAT program. The significant results of seedling media (SM), planting media (PM) and their combinations (SM x PM) were compared by the method of LSD at 5% probability for mean difference values (Nissen, 1982).

RESULTS

The results for the statistical analysis of variance of all the sensory characteristics are given in the Table I. which clearly indicates that the main effects of SM of the parameters fruit firmness and fruit flavour are non-significant, whereas the others are from significant to highly significant at $P<0.5$ and $P<0.1$, respectively.

For the parameter of fruit colour, Table II depicts a dominant behavior of soil-based compost followed peat compost and perlite in the SM. In case of PM, border soil was ranked in the top; whereas, grapes marc was declared for the least mean values. As for interaction, the combination of soil-based compost (SM) x border soil (PM) ousted for top mean value (Fig. 1).

The results of the characteristic of fruit firmness for PM, straw bale and grapes marc was identical and that both

Table I. Results of statistical analysis of various characteristics of tomato fruits

Parameter	Source of variance			Coefficient of Variation (%)
	Seedling Media (SM)	Planting Media (PM)	SM x PM	
Fruit colour	**	**	*	6.50
Fruit firmness	*	NS	*	5.99
Fruit flavour	**	NS	**	5.43
General likeness	**	**	*	4.02

*=Significant, **=Highly significant, NS=non-significant

Table II. Effect of seedling and planting media on the sensory attributes of tomato fruits

ˣParameters	Main Effect (ME) of							
	*Seedling Media (SM)			+Planting Media (PM)				
	SBC	PER	PC	SBC	PER	SB	GM	BS
1	4.55a	4.09c	4.34b	4.37b	4.34b	4.31b	3.90c	4.71a
2	4.06	3.99	4.11	3.91b	4.00ab	4.21a	4.16a	4.00ab
3	4.04	3.86	3.97	4.06a	3.83b	4.23a	3.58c	4.09a
4	4.21a	4.00b	4.13a	4.10bc	4.06cd	4.23ab	3.91d	4.27a

*In seedling media: SBC=Soil-based compost, PER=Perlite, PC=Peat compost; +In planting media: SBC=Soil-based compost, PER=Perlite, SB=Straw bales, GM=Grapes marc, BS=Border soil; ˣIn parameters: 1=Fruit colour, 2=Fruit firmness, 3=Fruit flavour, 4=General likeness of fruit;

Note: a) The mean values of SM and PM without indicating alphabets are non-significant

b) Values having similar alphabets do not differ to each other

were ranked for dominate position. Border soil and perlite had the close mean values and were placed in the middle. However, soil-based compost was awarded for the lowest performance (Table II). The combinations soil-based compost (SM) x grapes marc (PM), soil-based compost (SM) x straw bale (PM) and peat compost (SM) x straw bale (PM) responded in a similar style with no marked differences of mean values (Fig. 2).

In case of the parameter of fruit flavour, Table II elucidates the superiority of straw bale, border soil and soil-based compost over perlite and grapes marc in the main effect of PM. The former three media behaved in a similar fashion while the latter responded differently and were ranked for second-last and last order of preferences, respectively. As for SM x PM, the combination of soil-based compost (SM) x straw bale (PM) was in the top. The combination peat compost (SM) x border soil (PM) and soil-based compost (SM) x soil-based compost (PM) behaved identically and ranked in the 2nd order. The combination perlite (SM) and grapes marc (PM) showed the minimum performance (Fig. 3).

In the parameter of general likeness, perlite of SM had lower values than soil-based compost and peat compost, however, border soil of PM demonstrated highest performance while, grapes marc showed the poorest performance as shown in Table II. From the Fig. 4, it is clear that all the combinations, except two, had the interacted mean values. The combination, soil-based compost (SM) x straw bale (PM) superseded over all the other combinations. In contrast, the combination perlite (SM) x grapes marc (PM) was investigated for the lowest performance.

DISCUSSION

During ripening of tomato, many physical and chemical changes appear which have a direct influence on sensory attributes (Butt & Al-Haq, 1991). The important sensory features including colour, flavor and aroma, hardness (firmness) etc. are of vital significance from the standpoint of acceptability of fruit as a food product and for the purpose of fresh-fruit marketing. Neither a single variety meets the absolute standard requirements nor a single growing medium effect identically on different tomato varieties in terms of a quality trait for sensory features of tomato rather a good quality fruit is the assembling of several interacting factors.

Tomato colour is an important quality characteristic. Standard colour is difficult to find because of numerous tomato varieties and each one has its own colour intensity at the time of maturity. From the data it is concluded that almost all planting media in combination with perlite (SM) had obtained relatively lower reward of fruit colour, indicating that perlite as seedling, planting or in combination with other media received less points for colour parameter. Most of the fruits being developed or sourced from perlite medium provided airy environment to the plant-part underneath the soil, which caused to improve the size and weight of fruit. During this course of time, the fruits derived from other media turned mature a bit earlier lowering the fruit colour from the plants grown in perlite medium. The development of better quality colour in the fruits of greenhouse border soil or soil-based compost could be attributed to high temperature of rooting horizon that developed lycopene relatively in higher concentration and at an early stage in comparison with perlite. Perlite grown fruits may have slow activation of metabolites for red pigmentation, which is the result of lycopene synthesis at maturity stage. Colour values of red tomato varieties were found to be highly correlated with lycopene contents that might appear in the fruits grown in soil-based compost (Johjima & Matsuzoe, 1995a). However, for the marketing of fresh-fruit tomato at too far distances or for longer shipment, full red colour of cultivar *Correct* F_1 tomato variety may not be recommended as the fruit becomes soft while reaching in the hand of consumers thus light red colour (as recommended by USDA) could be acceptable. Red colour may appear after few days of full maturity as the chlorophyll degradation commenced followed by carotenoid biosynthesis (turning stage) and the fruit were fully ripe within 7-10 days of reaching the turning stage as reported by Johjima and Matsuzoe (1995b). Batu (1996) seconded these results, describing that during the stage of light red colour, the fruit gets its full size and further keeping it on the plant would merely homogenize the colour by faster

Fig. 1. Effect of SM x PM interaction on the fruit colour of tomatoes

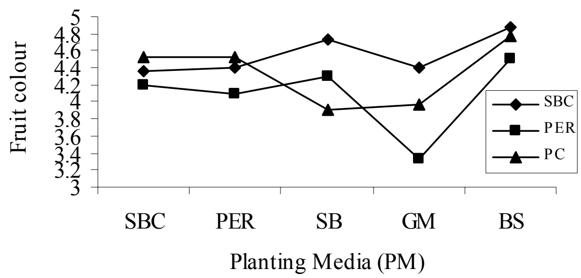


Fig. 2. Effect of SM x PM interaction on the fruit firmness of tomatoes

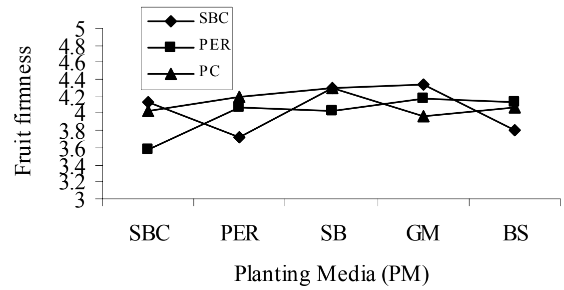


Fig. 3. Effect of SM x PM interaction on the fruit flavour of tomatoes

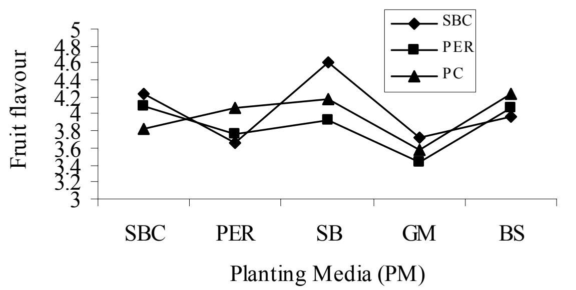
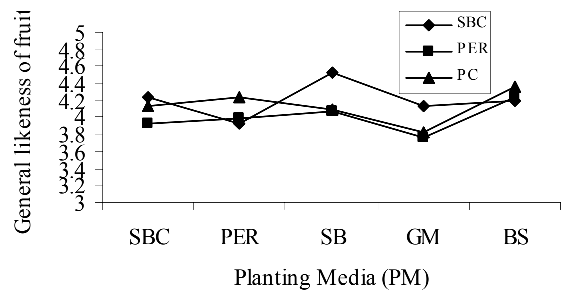


Fig. 4. Effect of SM x PM interaction on the general likeness of tomato fruit



biological and physiological mechanism.

Fruit firmness is basically a varietal characteristic and every genotype possesses certain inheritance in terms of this parameter (Butt & Al-Haq, 1993). It is also closely related to the environmental condition, type of plant nutrition, soil type in different locations etc. However, the most important factor of fruit firmness could be correlated with the maturity and duration of maturity in a certain growing medium. Another factor is the presence of pectin in tomato fruit. Pectin is the natural constituent of ripe tomato, which acts as cementing agent and is formed between the microscopic cells to bind together the fleshy red tissues. The growing plant forms first an insoluble protopectin that binds the cells firmly together. At full maturity, protopectin is changed into pectin, which still holds the cells in place but less rigidity, so that the fruit is no longer too hard. Further growth of tomato allows the pectin itself to be broken down into soluble compounds, which have little binding power, so that over-ripe fruit is soft. It is added that from the pink stage of ripening to the full red-ripe stage, there is a large increase in available pectin (Gould, 1979). It appears that the tomato fruits harvested from the plants grown in grapes marc or straw bale or their combinations with soil-based compost or peat compost might have more protopectin at initial stage and in later stage, more concentration of pectin to keep the fleshy tissues relatively firmer which in turn, can be associated less watery fruits in comparison with the fruits taken from perlite and / or border soil PM. The results are also in line with Dundar and Sivritepe (1995).

Tomato fruit undergoes a number of physical and chemical changes during the course of its ripening. Important changes take place in its colour, texture, flavor and aroma and thus its quality (Butt & Al-Haq, 1993). Like colour trait, the parameter, flavor can be placed equally in the process of marketing. A number of volatile flavor components of tomato have been reported. Compounds, which are important to tomato flavor, are hex-cis-3-enal, beta-ionone, decan-trans, trans-2, 4-dienal and 2-isobutylthiazole (Gould, 1979). The PM of straw bale, border soil and soil-based compost developed fruit flavor statistically identical. Grapes marc could not produce quality flavor fruits. Straw bale (PM) with soil-based compost (SM) proved the best performance followed by border soil and soil-based compost (PM) with soil-based compost (SM). Grapes marc (PM) in combination with perlite (SM) gave the fruits of minimum flavor. These results indicate that seedling derived from soil-based compost when grown into straw bale and / or border soil resulted in the production of high quality flavor fruits. These variations might be associated with chemical and biological occurrence during the course of plant and fruit development. High quality flavor fruits are proved to have less water percentage (i.e.

more dry matter and / or TSS contents). Similarly the uptake of crop nutrients for any cultivar of tomato can be manipulated to promote taste and flavor components (Hobson, 1995). Nevertheless, grapes marc alone or in combination could not develop quality flavor due to osmotic stress or water deficit inhibited the vegetative growth of plant and consequently, influence on the quality flavor production. The low capillary movement of nutrients may cause a rapid osmotic stress that was observed especially in the leaves and partially on the stem of the plant grown in the grapes marc PM, subsequently, inhibited good flavor fruit, which is in agreement with Turhan (1997).

General likenesses of tomato fruits is employed to test initially the actual consumer acceptance or rejection of fresh tomato crop. The fruits of relatively higher dry matter and TSS contents with good flavor have more likeness for consumption. The general acceptance for good taste of tomato is determined by the ratio of sugars to acids and such fruits are usually less watery and comparatively smaller in size plus lower in weight. In other words, the general likeness of tomato fruit is mainly based on its quality because of the competitiveness in the fresh tomato market (Ho, 1995).

CONCLUSIONS

Seedlings and the subsequent transplants of greenhouse tomatoes (*Lycopersicum esculantum*) grown hydroponically by using different substrates of organic and inorganic nature, when compared with the border soils, have strong influence on a number of qualitative sensory characteristics which have a deep impact on the premium and value-added price of tomatoes. The same technique can be employed to several other horticultural crops of commercial importance.

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