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Plant Spacing and Cultivar Affects Yield Components, Qualitative Traits and Early Ripening of Tomato (*Lycopersicon esculentum*)

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Abstract

Two-year field trial was set up on sandy clay soil in the Jiroft and Kahnouj Agricultural Research Center with the objective to determine the effect of plant spacing and different cultivars on the yield and qualitative characteristics of tomato (*Lycopersicon esculentum*). This experiment was performed as split plot based on complete randomized block design with 3 replications. The main plots were in – row spacing in 4 levels include 0.3, 0.4, 0.5 and 0.6 m and the subplots were cultivars naming 'Shef', 'Peto Early CH' and 'FDT 202'. The results showed that, fruit length to diameter ratio, total acidity, fruit number per plant, mean fruit weight, yield per plant, total yield and first harvest to total harvests ratio were significantly affected by plant spacing. In addition, cultivars showed significant effect on all traits evaluated ($p<0.01$). In this experiment, fruit length to diameter ratio and total acidity increased as plant spacing increased, however it had no effect on total soluble solids. In this study, total fruit yield is being increased while the yield per plant, number of fruit per plant and fruit weight is being reduced by increased number of plants per unit area. Although among tomato cultivar, 'Peto Early CH' had a higher yield over other cultivars, but cultivar 'Shef' showed higher yield in the first harvest. Generally it seems according to the results collected that plant spacing 0.3 m and 'Shef' cultivar owing to better adaptation and higher commercial yield for production in Jiroft city is suggested.

Keywords: acidity, density, fruit weight, total soluble solids, yield

Introduction

Tomato (*Lycopersicon esculentum* Mill) is one of the most important fruit vegetable over the world and the largest in the cultivation and production among vegetables (FAO, 2008). Although traditional agriculture was based on the use of low yielded varieties and low planting density, but attitudes has moved in modern agriculture towards dense planting and applying varieties with high yield potential. Maximum yield is resulted at optimum plant density which depends upon cropping system and cultivar (Dong *et al.*, 2006). It is believed that yield per unit area tends to increase with plant density up to certain threshold, and then decline due to interplant competition (Duthie *et al.*,1999). Plant density per unit area determines the optimal above ground conditions that allows the plant to acquire the essential growth elements (light, CO_2, etc.) that influence the productivity of dry matter and hence the final yield (Ibrahim, 2012). Under higher plant density, plant growth rate is decreased due to reduced light interception per plant (Heuvelink, 1995). In close spacing because of an inadequate supply of photosynthesis due to shading, detrimental effect on fruit set were observed (Papadopoulos and Pararajasingham, 1997). It has also been reported that at lower plant density in tomato, fruit weight, fruit size and yield per plant decreased, whereas total yield increased (Silva *et al.*, 1992). Research conducted with other vegetable species showed similar reactions to those of tomato. In cucumber and watermelon fruit number, fresh weight of fruit and yield per unit area is being increased, while the yield per plant and fruit weight is being decreased by increased number of plants per unit area (Edelstein and Nerson, 2001; Staub *et al*, 1992). In most regions of Iran, tomato cultivated in spring and summer, however in some parts such as Jiroft city according to growth conditions like suitable temperature, tomato production take place as out of season in short tunnels. Jiroft is a commercially important production site for vegetables crops in Iran. There is little information on proper cultivar selection and plant spacing for maximum yield and their interaction on qualitative traits and early ripening of tomato. The objective of this case study was to evaluate the effect of plant spacing on qualitative and quantitative characteristic of tomato cultivars in a short tunnel and ultimately achieve the optimum plant spacing and suitable cultivar for early ripening in open field condition.

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Materials and Methods

Experimental Site and Field Management

This experiment was conducted at Jiroft and Kahnouj Agriculture Research Center of Jiroft, Iran (28° 32´N and 57°32´E and altitude 628 m above mean sea level) in soil with sandy clay (Fie loamy, mixed, hypertermic typic turifluentcoars loamy). Seed sow was performed in nursery plots in early December for two years experiment. Approximately 10 days after planting the seeds began to emerge. In the nursery the row distance is about 10 cm. In the first half of January of each year healthy seedlings were transplanted in the field under plastic cover (short tunnel). Each sub plot was made up of two culture lines 8 meters length and furrow width of 0.4 m. Date of first harvest was the second half of April in each year and next harvests were performed in 10-14 day intervals. In all treatments nutrition was programmed based on soil test and amounts of N (urea, 150 Kg h^{-1}) P (Triple Super Phosphate: 200 Kg h^{-1}) K (Potassium Sulfate: 400 Kg h-1), pH= 8.3 were added to growing media.

Measurement of Traits

After the harvest of tomatoes, qualitative and quantitative traits including fruit length to diameter ratio, total soluble solid, acidity, number of fruit per plant, fruit weight, yield per plant, total fruit yield and first harvest to total harvests ratio were measured. After harvesting, fruits were weighed by digital balance. For yield and yield components measurement, ten plants from each plot were randomly selected. Total soluble solid was estimated by refractometer. Acidity was determined by titration using phenolphthalein solution (0.1 N) as indicator and predominant acid of tomato, citric acid, was reported. Fruit ripening has been considered when the fruit was firm and very red in color.

Experimental Design and Statistical Methods

Split-plot trial was set according to complete randomized block design. The main plots were the four rows spacing (0.3, 0.4, 0.5 and 0.6 m) and subplots were three cultivars ('Shef', 'Peto Early CH' and 'FDT 202'). The experiment was performed for 2 consecutive years (2005 and 2006) with three replications. All data were subjected to analysis of variance (ANOVA), and separated by Duncan's multiple range tests performed using SAS.

Results

Fruit Length to Diameter Ratio

Analysis of variance indicated that cultivar and plant spacing had significant effect on fruit length to diameter ratio, whereas their interaction did not significantly influence on this trait (Tab. 1). With increasing spacing, fruit length to diameter ratio increased so that the highest and the lowest fruit length to diameter ratio were observed in spacing 0.6 and 0.3 m respectively (Tab. 2). On the other hand, cultivars 'Peto early' and 'Shef' showed the highest fruit length to diameter ratio in comparison with 'FDT-202' (Tab. 2).

Total Soluble Solid

TSS is an index of soluble solids concentration in fruit (Javanmardi and Kubota, 2006). In this study, cultivar and interaction between cultivar × plants spacing significantly affect total soluble solid, while there was no influence of plant spacing on observed total soluble solid (Tab. 1 and Fig. 1). As can be seen from Tab. 2 although there was no significant difference between different plant densities, however, the highest total soluble solid was related to plant density 0.6 m. In addition, among different cultivar, 'FDT-202' showed a higher total soluble solid.

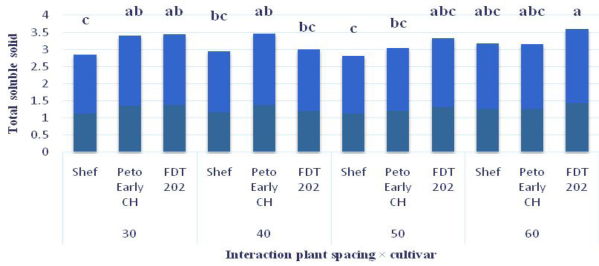


Fig. 1. Interaction between plant spacing × cultivar on total soluble solid

Total Acidity

Results showed that main effects and interaction plant spacing × cultivar had significantly ($P < 0.05$) effect on total acidity (Tab. 1 and Fig. 2). The highest and the lowest acidity were related to the spacing of 0.6 and 0.3 m, respectively. Moreover, 'FDT-202' cultivar had higher total acidity than other cultivars (Tab. 2).

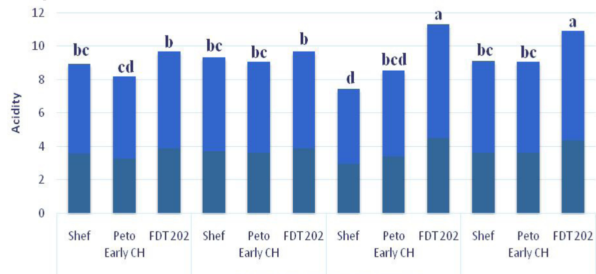
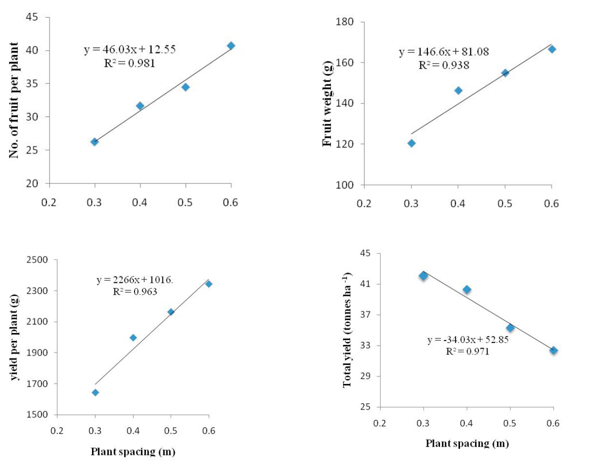


Fig. 2. Interaction between plant spacing × cultivar on acidity

According to Tab. 1, significant differences were observed in number of fruit per plant due to plant spacing and cultivar treatments. However, interaction between plants spacing × cultivar was not significant (Tab. 1). In this study, align with increasing plant spacing, number of fruit per plant increased so that the highest and the lowest number of fruit per plant were achieved in spacing of 0.6 and 0.3 m respectively (Tab. 2). There was a positive linear relationship ($P \le 0.01$) between plant spacing and number of fruit per plant (Fig. 4).

(a) (b)



(c) d)

Fig. 4. Relationship between plant spacing and number of fruit per plant (a), fruit weight (b), yield per plant (c) and total yield (d)

Fruit Weight

Analysis of the results of this experiment showed that plant spacing and cultivar significantly affected fruit weight (Tab. 1). The interaction among plant spacing and cultivar was significant for fruit weight (Tab. 1 and Fig. 3). As shown in Tab. 2, with decreasing space, fruit weight significantly decreased. 'FDT-202' showed higher fruit weight over other cultivars (Tab. 2). There was a positive relation between plant spacing and fruit weight (Fig. 4).

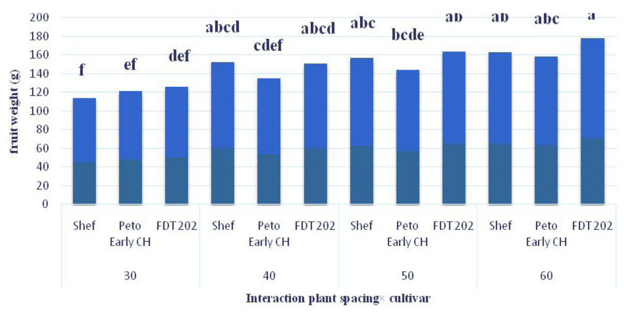


Fig. 3. Interaction between plant spacing × cultivar on fruit weight

Yield Per Plant

The yield per plant was significantly ($p < 0.01$) affected by cultivar and plant spacing (Tab. 1). In this experiment with decreased spacing, yield per plant considerably decreased so that the highest and the lowest yield per plant were observed at spacing of 0.6 m and 0.3 m, respectively. The results concerning yield per plant are given in Tab. 2. Among cultivars studied, 'Peto early CH' had higher yield per plant compared with other two tested cultivars (Tab. 2). In this research a linear increase was found in fruit yield when plant density is increased (Fig. 4).

Total Yield

The plant density significantly influenced total yield (Tab. 1). In this experiment total yield increased by decreasing in-row space (Tab. 2). The highest total yield was obtained 42.09 tones.ha-1 at higher plant density (0.3 m) (Tab. 2). In addition, cultivars responded differently to the plant densities on total fruit yield per plant. 'Peto early' performed better compared with other two cultivars, mostly due to more the number of fruit per plant and yield per plant (Tab. 2). The negative linear relationship between plant space and total yield was observed with all cultivars (Fig. 4).

First Harvest to Total Harvests Ratio

This attribute is the primary indicator for early ripening. There are significant differences ($p < 0.01$) between levels of plant space and cultivars in relation to first harvest to total harvests ratio (Tab. 1). In this experiment with increasing plant space, yield of the first harvest to total harvest decreased, so that the highest (13.5%) and the lowest (11.2%) first harvest to total harvests ratio were achieved in spacing 0.3 and 0.6 m, respectively (Tab. 2). Among the varieties also, 'Shef' cultivar with 14 percent showed considerable and significant superiority in comparison with other cultivars (Tab. 2).

Discussion

The present study revealed that the plant spacing and cultivar can affect yield components, qualitative traits and early ripening of tomato. It was apparent that at higher plant density, fruit length to diameter ratio decreased, which may be attributed to severe competition between vegetative and reproductive organs and consequently can be followed by decreasing fruit size. In agreement with our findings, Papadopoulos and Ormrod (1990) and Streck *et. al.* (1998) reported that fruit size significantly decreased with smaller planting distance. Total soluble solid and acidity are the most important fruit quality characteristics.

Tab. 1. Analysis of variance for *Lycopersicon esculentum* to evaluate effects of plant spacing and cultivar treatments on studied traits

		Mean squares							
Source of variation	df	Fruit length to diameter ratio	Total soluble solid	Acidity	Number of fruit per plant	Fruit weight	Yield per plant	Total fruit yield	First harvest to total harvests ratio
Year (A)	1	0.051^{ns}	0.355^{ns}	1.067+	29.32*	339.9^{ns}	567613**	9.96^{ns}	4.18*
Replication ×year	4	0.038	0.214	0.422	462.95	7175.4	74944	51.49	2.55
Plant spacing (B)	3	0.075*	0.219^{ns}	1.913*	647.97**	6872.3**	1598578**	359.4**	17.27**
A × B	3	0.004^{ns}	0.02^{ns}	0.045^{ns}	3.78^{ns}	1.5**	19240^{ns}	8.6^{ns}	0.007^{ns}
Erorr1	12	0.016	0.118	0.6	5.21	75.27	21370	7.45	0.49
Cultivar (C)	2	0.192**	1.10**	23.134**	1210**	1332**	1294320**	211.3**	268**
A× C	2	0.011^{ns}	0.018^{ns}	0.011^{ns}	1.09^{ns}	0.291^{ns}	31503^{ns}	3.32^{ns}	0.11^{ns}
B× C	6	0.004^{ns}	0.29**	3.88**	3.01^{ns}	232**	28061*	1.45^{ns}	0.20^{ns}
A × B × C	6	0.0003^{ns}	0.015^{ns}	0.02^{ns}	1.21^{ns}	0.051^{ns}	9085^{ns}	1.79^{ns}	0.00008^{ns}
Error 2	32	0.005	0.029	0.439	4.88	54.68	11176	2.17	0.21
CV%		6	6	8	7	6	6	4	4

*: Significant at $P < 0.05$. **: Significant at $P < 0.01$. ns: not significant.

Tab 2. Effects plant spacing (m) and cultivar on qualitative traits and yield components of tomato

	Treatments	Fruit length to diameter ratio (cm)	Total soluble solid (%)	Acidity (%)	Number of fruit per plant	Fruit weight (g)	Yield per plant (g)	Total fruit yield(t/h)	First harvest to total harvests ratio
Plant spacing	0.3	1.15^{b}	3.22^{a}	8.95^{b}	26.27^{d}	120.5^{d}	1643^{d}	42.09^{a}	13.5^{a}
	0.4	1.18^{b}	3.14^{a}	9.37^{ab}	31.67^{c}	146.3^{c}	1997^{c}	40.31^{a}	12.11^{b}
	0.5	1.23^{ab}	3.06^{a}	9.09^{b}	34.47^{b}	154.9^{b}	2163^{b}	35.35^{b}	11.55^{c}
	0.6	1.30^{a}	3.32^{a}	9.69^{a}	40.68^{a}	166.5^{a}	2343^{a}	32.4^{c}	11.32^{c}
Cultivars	Shef	1.26^{a}	2.94^{b}	8.71^{b}	31.73^{b}	146.6^{b}	2054^{b}	38.59^{b}	14.42^{a}
	Peto Early CH	1.27^{a}	3.27^{a}	8.72^{b}	41.03^{a}	139.8^{c}	2259^{a}	39.28^{a}	13.64^{b}
	FDT 20	1.12^{a}	3.35^{a}	10.41^{a}	27.08^{c}	154.7^{a}	1796^{c}	34.2^{c}	8.28^{c}

Different letters within a column indicate significant difference according to Duncans multiple range test ($P < 0.05$)

The fact that total soluble solid was not affected by plant spacing. However cultivar and interaction between cultivar and plant spacing significantly affected total soluble solid. In this research, plant spacing and cultivar as well as their interaction significantly influenced the amount of acidity. Cultivar 'FDT-202' had higher total acidity over the other two tested cultivars. Because of citric acid (vitamin C) is the predominant organic acid of tomato (Pedro and Ferreira, 2007), hence 'FDT-202' cultivar could be recommended for fresh table consume. Qualitative of genotype rather than plant density (Ban *et. al.*, 2006). We found significant effect of plant spacing and cultivar as well as their interaction on fruit weight. The experimental results indicate that with decreasing space, average fruit weight also decreased. Fruit weight is an important characteristic because of consumers' preference (Ban *et. al.*, 2006). Reports emphasize that assimilate distribution to the fruits in tomato strongly depends on the number of fruits (sinks) per truss (Heuvelink and Buiskool, 1995). The weight of individual fruits increased with decreasing number of fruits per plant, albeit less than proportionally

(Heuvelink, 1997). Our results showed that, the number of fruit per plant increased linearly as plant spacing increased. Our findings are in agreement with Ban *et. al*. (2006) on *Cucumis melo* who mentioned that space increasing caused increasing of number of fruit per plant and they also reported that there is a linear increase in number of fruit per plant when plant space is increased. This could be due to the fact that at higher plant density flower abortion occurrence increases (De Koning and De Ruiter, 1991). Total yield was significantly decreased with increasing plant space in both 2 years of research. In our experiment, at row space of 0.3 m total yield was in average 30% higher than 0.6 m. The decrease in total yield per area in case of with increased planting distance decrease could be attributed to reduction in number of plants per unit area (Walters and Schultheis, 2000). Also, it can probably be because of less spacing which created higher interplant competition (Daþgan and Abak, 2003). Similar findings have been reported on melon (*Cucumis melo* L) by Ban *et al.* (2006), watermelon (*Citrullus lanatus* (Thumb.) by Edelstein and Nerson, (2001). 'Peto Early CH' had higher total yield compared with 'Shef 'and 'FDT-202' due to higher yield per plant and number of fruit per plant. Early ripening is one of major parameter determine economic value. In fact, treatments resulting early ripening, increasing yield of the first harvest and are higher commercial desirability. At the tested planting space, cultivars responded differently based on the ratio of the first harvest to total harvest. Accordingly, it can be concluded that although the total yield decrease at cultivar 'Shef', it can be compensated by increasing the first harvest (early ripening) and hence increased profitable.

Conclusion

According to findings of this study, it is concluded that planting space and cultivar affect on the productivity of tomato plants and therefore plant spacing could be practiced to increase yield of tomato. Since Jiroft is a commercially important production site for vegetables crops in Iran, it is recommended that local growers use plant spacing 0.3 m and cultivar 'Shef' in order to increase production in the off-season, to enhance their profitability and economic efficiency.

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