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Determination of Relationships Between Number of Stem and Yield of Tomato (*Lycopersicon lycopersicum* L.)

Ali Ece and Nilay Darakci
Department of Horticulture, Faculty of Agriculture, Gaziosmanpasa University,
60240 Tokat, Turkey

Abstract: In this study, relationships between number of stem and yield were investigated for some indeterminate tomato varieties. Two different stem applications (single and double-stem) and ten different indeterminate tomato varieties were used. Experiments were carried out at randomized blocks split plots experimental design with three replications during the years 2004-2005. Stem applications were applied in main blocks and varieties were applied in sub-plots. Plant total yield (kg plant^{-1}), total number of fruit per plant (number plant^{-1}), marketable plant weight (g) and marketable yield (t ha^{-1}) were taken into consideration. Correlation and path analysis were carried out between marketable yield and the other plant characteristics. It was observed that plant total yield and number of fruit per plant had significant and positive effects but number of stem had negative effects on marketable yield of tomato. Then, it was concluded that varieties with higher total yield, total number of fruit and adaptation capability should be selected and single stem application should be implemented for higher and quality marketable yield in tomato.

Key words: Tomato, correlation analysis, yield, variety, stem number

INTRODUCTION

Tomato is a South-America originated vegetable and one of the most widely cultured plant over the world. There is a recent increase in tomato cultured lands and tomato yields (Anonymous, 2006). This increase may result from the development of new high-yield hybrid varieties and new culture techniques.

Temperature demand of tomato is between 15-28°C for the best growth. Proper growth also takes place at temperatures over 30°C and flowers are formed at these temperatures but fertilization problems and consequently yield decreases occur at high temperatures (Vural *et al*., 2000). Although tomato does not enjoy high air humidity, existence of always available water around the root zone provides proper and high yield conditions. Climate demands are important factors for variety selection in open-air culture.

Determination of variety characteristics in new-variety development studies constitutes the main objective of breeding programs. In these studies, adaptation capabilities of varieties for different regions, their resistance to plant diseases, fruit quality and etc. characteristics are investigated (Thomas, 1986). During the recent years, greenhouse indeterminate tomato varieties were successfully grown in open-air. Although controlled conditions are not provided in open-air; varieties have exhibited significantly high performance with regard to yield and fruit quality (Cuertero and Baguena, 1980; Saglam, 1994; Karatas *et al*., 2002). However, plant characteristics vary under various climate conditions; that brings the need for new studies to be carried out with tomato varieties in different regions.

Tomato has a direct respond to cultural techniques. Fruit size, plant yield and early rising increase with increasing land space per plant (Günay, 1981). Cuertero and Baguena (1980), Varis (1985), Tsambanakis (1987) and Stoica and Ilie (1990) reported yield changes with number of plant sown over per unit area. Proper fertilization has also a significant effect on tomato yield. Amount of fertilization and mineral material content are effective both on yield and fruit quality (Alan *et al*., 1992; Bagal *et al*., 1992; Ohta *et al*., 1993). Tomato producers usually prefer gravity irrigation methods. Recent studies about drip irrigation method for tomato indicated a better water utilization and fertilizer application (Rubeiz *et al*., 1990). Pruning methods applied in tomato culture vary and plant yield also varies with pruning methods. For instance, while double-stem pruning method carried out in spring season has negative effects on yield and quality; pruning has positive contributions on yield when carried out in fall season (Bas and Sevgican, 1990).

Corresponding Author: Ali Ece, Department of Horticulture, Faculty of Agriculture, Gaziosmanpasa University, 60240 Tasliciftlik, Tokat, Turkey Tel: +90 0356 2521616-2134 Fax: +90 0356 2521488

Researchers have reported significant linear correlations between yield and number of fruit per plant, mean fruit weight, fruit size, number of cluster per plant and number of sprouts per plant (Singh *et al*., 1990; Singh *et al*., 1993). Singh *et al*. (1990) determined that number of fruit, fruit size and fruit weight have direct impact on fruit yield.

Continuously new tomato varieties are introduced into markets by the companies trying to increase their market share. That is why; there is a need for performance determination of varieties in different regions. For an economical tomato culture, first of all, proper variety for the region and cultural techniques to be applied should be well-known.

In this study, relationships between number of stem and yield were investigated for some indeterminate tomato varieties.

MATERIALS AND METHODS

This study was carried out under Tokat-Turkey ecological conditions during the years 2004-2005. Tokat is located in the northern Turkey, which is generally known as Mid-Black Sea region. Astona F1, Menhir F1, Volare F1, Sümela F1-RN, Töre F1, BT 131 Gülle F1, Cemile F1, Alida F1, Diyansa F1 and Newton F1 indeterminate tomato varieties have constituted the plant material of the study.

Soils of study area have high pH values and low organic material content. Experiments were carried out under producer conditions. Producers have applied traditional fertilization programs in previous years without carrying out any soil analysis. That is why, significantly high levels of available phosphorus and potassium were observed in study area during the first year of the study (Table 1). A fertilization program proper for the soil analysis results was followed in this study.

During the study years of 2004 and 2005, all of the climate data were higher in the second year than the first year. Second year had higher temperatures, precipitation and relative humidity (Table 2).

Experiments were carried out at randomized blocks split plots experimental design with 3 replications; stem applications (single and double stem) were placed in main blocks and varieties were applied in sub-plots. Seeds were sown on 10 April 2004 during the first year and on 11 April 2005 during the second year of the study. Then the mature seedlings were planted over the experimental land on 24 May 2004 during the first year and on 15 May 2005 during the second year of the study. Row spacing was 75 cm and on-row spacing was 40 cm for single-stem culture and these values were 75 and 60 cm, respectively for double-stem culture. In each method, 10 plants were placed in each plot. Drip irrigation method was applied to meet the water requirements of the plants. Fertilizers were applied via drip irrigation method (Rubeiz *et al*., 1990). To terminate the plant growth, two leaves were left after the 8th cluster and by this way growing tip was broken-off and tip-taking was carried out (Campos *et al*., 1989). All the other maintenance works were also regularly carried out during the experiments.

In this study, plant total yield (kg plant^{-1}), total number of fruit per plant (number plant^{-1}), marketable plant weight (g) and marketable yield (t ha^{-1}) characteristics were taken into consideration. Marketable plant weight and marketable yield values were determined

Table 1: Soil analysis results for study area

Years	Depth (cm)	Saturation (%)	Total salt (%)	pH	Lime (%)	Available P	Available K	Organic material (%)
2004	0-20	53	0.020	7.98	7.0	18.8	108.5	1.47
2005	0-20	45	0.014	8.01	12.3	6.2	46.2	1.14

Table 2: Climate data for study years

	Average temperature (°C)		Maximum temperature (°C)		Minimum temperature (°C)		Monthly total precipitation (mm)		Relative humidity (%)	
Months	2004	2005	2004	2005	2004	2005	2004	2005	2004	2005
April	11.3	12.3	30.5	28.6	-8.3	-3.6	32.0	67.0	65.2	70.5
May	14.9	15.2	30.1	32.9	0.7	0.9	48.0	87.6	74.2	83.0
June	18.7	17.9	32.4	32.1	6.5	5.2	27.2	35.2	78.6	75.1
July	20.6	22.6	36.2	37.8	7.0	9.8	0.4	15.6	68.0	68.8
August	21.9	23.4	36.4	38.3	9.9	10.4	4.8	6.8	73.6	66.3
September	16.8	17.7	33.3	32.2	1.1	4.8	0.0	17.2	72.8	75.4
October	13.2	10.9	22.8	27.7	-1.4	-2.1	0.4	44.2	76.4	87.3
November	6.8	5.9	23.5	21.0	-10.4	-5.4	1.6	9.4	82.8	89.4
Total/Aver.	15.5	15.7	30.7	31.3	0.6	2.5	112.8	283.0	74.0	77.0

Source: Climate Records of Tokat Soil and Water Resources Institute by summing the weights of 1st and 2nd quality fruits specified by tomato standards of TSE (Turkish Standards Institute), Bad and Sevgican (1990). TARIST statistical software was used for variance analysis on experimental results and Duncan tests were run on statistically significant differences (Açikgöz, 1988).

RESULTS AND DISCUSSION

Single and double-stem applications and ten tomato varieties were taken into consideration in this study. Statistically significant changes were observed in total plant yield with regard to number of stem at 0.05 significance level during the first year and at 0.01 significance level during the second year of the study. Varieties have caused very significant changes on yield during both years of the study. A statistically significant change was not observed in number of stem×variety interaction. During both years of the study, plant total yields were higher in double-stem (6.00 and 4.19 kg plant^{-1}) than in single-stem (4.07 and 2.93 kg plant^{-1}). Variety averages were 5.77-4.69 kg plant^{-1} for the first year and 4.05-3.05 kg plant^{-1} for the second year. The highest yields observed in varieties of Newton F1 and Volare F1 during the year 2004 and in Sümela F1 RN during the year 2005. The lowest yields were observed in Cemile F1 and BT 131 Gülle F1 during the first year and in BT 131 Gülle Fi during the second year (Table 3).

Stem applications caused statistically significant changes in total number of fruit per plant during both years of the study at 0.05 significance level and varieties caused significant changes at 0.01 significance level. Double-stem has provided higher number of fruit than single-stem during both years of the study (49.10-38.60, 31.62-26.13 fruit plant^{-1}, respectively). Among the varieties, Volare F1 (48.22 fruit plant^{-1}) yielded the highest number of fruit per plant for the first year and Sümela Fi (36.97 fruit plant^{-1}) and Astona F1 (36.95 fruit plant^{-1}) yielded the highest numbers for the second year. The lowest values were yielded by Alida F1 (33.33 fruit plant^{-1}) in the year 2004 and by Newton F1 (28.87 fruit plant^{-1}) and BT 131 Gülle F1 (27.75 fruit plant^{-1}) in the year 2005.

As it can be seen from Table 3, statistically significant changes were observed among varieties with regard to marketable fruit weights at 0.01 significance level for both years. Average marketable weights of the varieties for the years 2004 and 2005 were between 142.39-113.66 and 120.23-104.84 g, respectively. During the first year of the study, Newton F1 and Alida F1 yielded the highest marketable fruit weights and Töre F1 and Menhir F1 yielded the lowest values. During the second year, while the highest values were obtained from Alida F1 and it was followed by Cemile Fi, the lowest values were obtained again from Töre F1.

Statistically significant changes were observed among only varieties with regard to marketable yield in both years. For the first year, varieties of Newton F1 (152.75 t ha^{-1}) and Volare F1 (152.46 t ha^{-1}) had the highest and BT 131 Gülle F1 (123.52 t ha^{-1}), Cemile F1 (123.85 t ha^{-1}), Töre F1 (124.86 t ha^{-1}) and Alida F1 (124.96 t ha^{-1}) had the lowest marketable yields. During the second year, Sümela F1 (107.64 t ha^{-1}) and Menhir F1 (103.55 t ha^{-1}) had the highest and BT 131 Gülle F1 (80.39 t ha^{-1}) had the lowest marketable yields (Table 3).

Double-stem application had statistically significant dominance over the single-stem with regard to plant total yield and total number of fruit per plant. Although a statistical significance was not observed in marketable fruit weight and marketable yield characteristics, in which fruit quality criteria were largely taken into consideration, numerical values were better in single-stem than double stem. Average values for all parameters obtained during the first year were rather higher than those obtained during the second year. Generally, high temperatures during the flowering period of tomato negatively affect the vigor of pollens. Also germination rates of pollens vary with plant genotypes (Çürük and Abak, 1995). When the climate data in Table 2 were evaluated, it can be seen that maximum temperatures during the second year of the study reached up to 37.8 and 38.3°C in July and August. This high temperature period was longer in the second year than the first year. This period coincide with the intensive cultural practices of the region. That is why, fertilization problems were experienced in most of the flowers formed at this period and that has caused the values of all parameters for the second year to be smaller than the first year.

Varieties have exhibited differences with regard to plant characteristics taken into consideration in this study. Genotype-dependent changes in plant characteristics were also emphasized in previous studies (Cuartero And Baguena, 1980; Saglam, 1994; Karatas *et al*., 2002).

During the first year of the study, marketable yield exhibited very significant and positive correlations with plant total yield, total number of fruit per plant and marketable plant weight (0.524**, 0.343** and 0.352**, respectively). While positive but insignificant correlation was observed between marketable yield and variety, insignificant but negative correlation was observed with number of stem. For the second year, marketable yield

Table 3: Mean values for some plant characteristics with regard to different stem number and different varieties

	2004			2005		
Varieties	Single-stem	Double-stem	Mean	Single-stem	Double-stem	Mean
Plant total yield (kg plant^{-1})						
Astona F1	4.38	5.85	5.11ab[1]	3.23	4.73	3.98ab
Menhir F1	4.17	5.46	4.81b	3.50	4.24	3.87a-c
Volare F1	4.51	7.01	5.76a	3.21	4.23	3.72a-d
Sümela F1-RN	4.26	5.86	5.06ab	3.42	4.68	4.05a
Töre F1	3.94	5.45	4.70b	2.88	3.84	3.36a-d
BT 131 Gülle F1	3.65	5.72	4.69b	2.45	3.66	3.05d
Cemile F1	3.65	5.72	4.69b	2.58	4.32	3.45a-d
Alida F1	3.81	5.60	4.71b	2.72	4.58	3.65a-d
Diyansa F1	3.82	6.33	5.07ab	2.68	3.70	3.19cd
Newton F1	4.64	6.91	5.77a	2.62	3.89	3.25b-d
Mean	4.07 b	6.00 a		2.93 b	4.19 a	
LSD	SN: 0.86 *	V: 0.83**	SN×V: ns	SN: 0.22**	V:0. 68**	Sn×V: ns
Total No. of fruit per plant (fruit plant^{-1})						
Astona F1	35.83	49.33	42.58ab	29.50	44.40	36.95a
Menhir F1	36.50	49.30	42.90ab	29.90	37.67	33.78a-c
Volare F1	37.20	59.23	48.22a	29.60	42.33	35.97ab
Sümela F1-RN	31.96	46.47	39.22bc	30.00	43.93	36.97a
Töre F1	32.47	49.47	40.97abc	27.63	39.97	33.80a-c
BT 131 Gülle F1	26.83	45.10	35.97bc	21.97	33.53	27.75c
Cemile F1	38.13	44.20	41.17abc	21.93	37.57	29.75bc
Alida F1	26.30	40.37	33.33c	22.80	36.87	29.83bc
Diyansa F1	29.00	47.90	38.45bc	24.20	35.77	29.98bc
Newton F1	32.03	49.57	40.80abc	23.80	33.93	28.87c
Mean	31.62b	49.10a		26.13b	38.60a	
LSD	SN: 4.24*	V: 6.17**	Sn×V: ns	SN: 3.21 *	V: 5.96**	Sn×V: ns
Marketable fruit weight (g)						
Astona F1	123.49	121.84	122.67bcd	112.49	109.48	110.99a-c
Menhir F1	114.97	112.35	113.66d	118.47	114.75	116.61ab
Volare F1	121.66	119.57	120.62cd	110.56	102.38	106.47bc
Sümela F1-RN	134.91	127.24	131.08abc	115.55	113.07	114.31a-c
Töre F1	123.22	111.55	117.39d	106.14	103.53	104.84c
BT 131 Gülle F1	138.82	127.80	133.31ab	119.66	112.71	116.18a-c
Cemile F1	129.28	113.20	121.24bcd	119.20	117.64	118.42a
Alida F1	145.90	135.93	140.92a	118.87	121.59	120.23a
Diyansa F1	132.71	132.73	132.71abc	113.14	111.95	112.54a-c
Newton F1	147.07	137.72	142.39a	113.25	115.30	114.27a-c
Mean	131.20	123.99		114.73	112.24	
LSD	SN: ns	V: 10.94**	SN×V: ns	SN: ns	V: 10.03**	SN×V: ns
Marketable yield (t ha^{-1})						
Astona F1	144.83	127.53	136.18ab	103.23	100.19	101.71ab
Menhir F1	137.98	119.37	128.68ab	115.43	91.66	103.55a
Volare F1	149.95	154.97	152.46a	105.02	91.02	98.02a-c
Sümela F1-RN	141.38	129.21	135.29ab	112.04	103.24	107.64a
Töre F1	129.83	119.89	124.86b	93.30	84.58	88.94a-c
BT 131 Gülle F1	120.64	126.39	123.52b	81.74	79.03	80.39c
Cemile F1	118.96	128.75	123.85b	84.64	93.41	89.03a-c
Alida F1	126.55	123.38	124.96b	89.05	95.74	92.40a-c
Diyansa F1	126.63	139.80	133.20ab	85.27	78.47	81.87bc
Newton F1	153.10	152.40	152.75a	84.75	79.32	82.04bc
Mean	134.98	132.17		95.45	89.67	
LSD	SN: ns	V: 21.95**	SN×V: ns	SN: ns	V: 18.113**	Sn×V: ns

SN: Number of Stem, V: Variety, *,**: Respectively 0.05, 0.01 significance level, ns: not significant, [1]: Means indicated with the same later fall into same statistical group

exhibited very significant positive correlations with plant total yield (0.424**) and significant positive correlations with total number of fruit per plant (0.324*). Contrary to second year data, while very significant and negative correlations were observed between marketable yield and variety (-0.511**); positive but insignificant correlations were observed with marketable fruit weight. Also, insignificant but negative correlations were observed with number of stem (Table 4). These findings support the results of Singh *et al.* (1990 and 1993).

Since there are also indirect impacts among plant characteristics, correlation coefficients were not able to

Table 4: Correlation of marketable yield with number of stem, variety and plant characteristics

Characteristics		2	3	4	5	6
Marketable yield	2004	-0.074ns	0.007ns	0.524**	0.343**	0.352**
	2005	-0.202ns	-0.511**	0.424**	0.324*	0.155ns
Number of stem	2004	1.000	0.000ns	0.802**	0.834**	-0.280*
	2005	1.000	0.000ns	0.778**	0.793**	-0.173ns
Variety	2004		1.000	0.020ns	-0.201ns	0.540**
	2005		1.000	-0.297**	-0.349**	0.226ns
Plant total yield	2004			1.000	0.917**	-0.025ns
	2005			1.000	0.930**	-0.042ns
Total number of fruit	2004				1.000	-0.394**
per plant	2005				1.000	-0.347
Marketable fruit weight	2004					1.000
	2005					1.000

Table 5: Results of path analysis on characteristics affecting marketable yield of tomato

	2004		2005	
Characteristics	Path coefficient	Percentage	Path coefficient	Percentage
Number of stem (Direct impact)	-1.356	50.88	-1.320	53.10
Variety (Over)	0.000	0.00	0.000	0.00
Plant total yield	1.274	47.81	0.810	32.60
Total number of fruit per plant	0.021	0.80	0.331	13.33
Marketable fruit weight	-0.013	0.49	-0.029	0.96
Variety (Direct impact)	-0.045	42.02	-0.087	15.22
Number of stem (Over)	0.000	0.00	0.000	0.00
Plant total yield	0.032	29.70	-0.308	53.92
Total number of fruit per plant	-0.005	4.77	-0.146	25.48
Marketable fruit weight	0.025	23.49	0.030	5.35
Plant total yield (Direct impact)	1.590	58.81	1.041	41.85
Number of stem (Over)	-1.087	40.22	-1.027	41.25
Variety	-0.001	0.03	0.025	1.03
Total number of fruit per plant	0.023	0.87	0.388	15.62
Marketable fruit weight	-0.001	0.04	0.005	0.23
Total number of fruit per plant (Direct impact)	0.025	0.98	0.418	16.64
Number of stem (Over)	-1.130	42.80	-1.046	41.67
Variety	0.009	0.34	0.030	1.21
Plant total yield	1.457	55.16	0.969	38.58
Marketable fruit weight	-0.018	0.70	-0.047	1.88
Marketable fruit weight (Direct impact)	0.047	9.42	0.136	23.75
Number of stem (Over)	0.380	75.58	0.228	39.79
Variety	-0.024	4.90	-0.019	3.43
Plant total yield	-0.040	8.04	-0.044	7.67
Total number of fruit per plant	-0.010	2.03	-0.145	25.33

fully indicate the relationship between characters. That is why path analyses were used to indicate the both direct and indirect impacts. Results of path analysis carried out over characteristics affecting the marketable yield were given in Table 5.

When the correlation coefficients in Table 4 were evaluated, it was seen that marketable yield exhibited significant and positive correlations with plant total yield and total number of fruit per plant in both years. However, plant total yield characteristic exhibited the highest positive direct impacts in both years. Indirect impacts of the same characteristic reazlied at the highest rate over stem application but coefficients of these impacts are negative. Number of fruit increases with increasing number of stem but plants are forced to feed more fruits and fruit weight and quality decrease. When the coefficients for the year 2004 were evaluated, it was seen that the highest secondary positive impacts came from marketable fruit weight. Linear positive impact rates of this characteristic (23.75%) were higher in the year 2005. The highest indirect impact of the same characteristic was realized positively over stem applications in both years. Number of quality fruits decreased with increasing number of stem but individual weights of marketable fruits increased. Again, based on correlation coefficients given in Table 4, it can be stated that a negative correlation existed between number of stem and marketable fruit weight in both years and a statistically significant relation was observed in the year 2004. Although number stem had a high rate of direct impact over marketable yield in both years (50.88 and 53.10%, respectively), these impacts had negative coefficients. While the indirect impacts of the same characteristic over plant total yield and total number of fruit per plant were positive, impacts over marketable fruit weight were negative. That indicates the existence of negative relations between the amount of market quality fruit and number of stem.

Observed significant and positive relations of marketable yield with plant total yield and total number of fruit per plant are in well-agreement with the findings of Singh *et al*. (1990).

CONCLUSIONS AND RECOMMENDATIONS

This study was carried out to determine the relationships between number of stem and yield for ten different indeterminate tomato varieties during the years 2004 and 2005. Following conclusions can be drawn from this study:

With regard to number of stem, although plant total yield and total number of fruit per plant characteristics were seen as statistically superior in double-stem application, it was observed that single-stem application was numerically superior in marketable yield and marketable fruit weight.

With regard to marketable yield, varieties exhibited changes with years. Relatively extreme temperatures arisen in the second year of the study and their duration has affected the performance of varieties. Average values for all characteristics were higher during the first year of the study. That brings a need to test the varieties under various climate conditions.

Following the correlation and path analysis, plant total yield and total number of fruit per plant had significant and positive contributions over marketable yield of tomato. Number of stem had negative effects on the same characteristic.

Finally, it was concluded that varieties with higher total yield, total number of fruit and adaptation capability should be selected and single stem application should be implemented for higher and quality marketable yield in tomato.

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