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EFFECTS OF SHADING AND ORGANIC FERTILIZERS ON TOMATO YIELD AND QUALITY

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Abstract

The present study was carried out to determine the effects of 50% shading and three different organic fertilizers [rice husk compost (RHC), broad bean green manure (B) and turnip residues (T)] on yield and quality parameters of tomatoes cv. Sumela F1 grown in the field. The plants grown in shade (50 %) had a higher ($p<0.01$) leaf chlorophyll content and leaf photosynthetic rate, fruit yield, firmness, soluble solids content (SSC), titratable acidity (TA) and vitamin C than those grown unshaded. The highest leaf photosynthetic rate (88.31μmol O_2 m^{-2} s^{-1}), fruit firmness (19.62 N) and fruit vitamin C content (38.44mg 100 g^{-1}) were obtained from turnip residues (T) treatment under shading. The highest values for SSC (5.6%), yield (3.97 kgper plant) and leaf chlorophyll content (46.68 CCI) were obtained fromshaded and broad bean green manure treatment.

Key words: Fertilizer; Photosynthetic rate; Stomatal conductance; Shading; Vitamin C.

Introduction

Tomato is an important source of antioxidants (lycopene, phenolic and vitamin C) for human nutrition. Such compounds are associated with a reduction in the risk of heart disease as well as various types of cancer (Rao & Agarwal 2000; Barber & Barber, 2002; Toor *et al.*, 2006). Organic and conventional fertilizers are used in tomato cultivation. However, in terms of human health, the use of organic fertilizers is important. Tomatoes grown by organic farming are reported to have higher vitamin C content than conventionally grown ones (Weibel *et al.*, 2000; Toor *et al.*, 2006; Özer & Uzun, 2013).

Vegetables should be grown organically because of their importance for human nutrition. Organic farming is a form of agriculture that is based on techniques such as crop rotation, green manure, compost, biological pest control and cultural measures. First of all, it is important to select organic fertilizers for organic vegetable production. It is important to use organic materials instead of using synthetic fertilizers in organic vegetable growing in order to increase soil productivity. That is why green manure, composts and other organic fertilizers should be used in cultivation of organic vegetables (Edward *et al.*, 2000; Ben *et al.*, 2007; Khan *et al.*, 2007; Lee *et al.*, 2012; Özer & Uzun, 2013).

Environmental factors such as light and temperature are the other important factors affecting vegetable cultivation. It is known that light has an important role in many physiological processes besides being an energy source for photosynthesis. Light is the most important factor affecting stomatal conductance and leaf chlorophyll content (Christie, 2007; Kilinç & Kutbay, 2008; Taiz & Zeiger, 2008). Shading is used to prevent excessive light intensity in agriculture. Shading also prevents plants from wind and hail storms, birds and insect transmitted virus diseases (Ilic *et al.*, 2012). El-Gizawy *et al.* (1992) reported the highest tomato yield with 35% shading, Ilic *et al.* (2012) also obtained highest yield with 40% shading. Both researchers indicated that shading eliminated sunscald on fruits.

Additionally, shading materials may provide several advantages at high summer temperatures (35- 40ºC) (Ilic *et al.*, 2012; Özer & Uzun, 2013; Ozturk *et al.*, 2014). The photosynthetic activity, which is sensitive to high temperature, decreases at extreme temperatures. The decline in photosynthesis activity is resulted from structural degradation of chlorophyll and chloroplasts (Dekov *et al.*, 2000; Cui *et al.*, 2006).

In this study, the influence of shading, stomal conductivity and chlorophyll content on photosynthesis mechanism of the plants was investigated. In addition, effects of different supplementary organic fertilizers (rice husk compost, broad bean green manure and turnip residues) on yield and quality of tomatoes were also studied.

Material and Methods

This study was carried out over the experimental fields of Ondokuz Mayıs University Agricultural Faculty (41º 37' 24.71"N, 36º 21' 11.02"E, 137 m altitude) in Samsun, Turkey. Tomatoes (*Solanum lycopersicon* cv. 'Sumela') were used as the plant material of the study. Seeds were planted on peat-filled seed trays (345 cells) on April 13-15 of both years. After emergence, seedlings were picked out at the stage of first true leaf appearance and transplanted into the seed trays (28 cells). The mixture of 2:1 ratio decomposed farmyard manure and garden soil was filled into the seed trays.

Experimental field was divided into 6 plots (9 x 4.6m) randomly for each organic fertilizer treatment. Organic fertilizers used to enrich raised seed beds (prepared at 1 m wide and 20 cm height) were prepared with rice husk compost (RHC), broad bean (B) (*Vicia faba* L. cv. Seher) green manure and turnip (T) (*Brassica napobrassica* L. cv. BT) residues. Some physico-chemical characteristics of organic fertilizers are provided in Table 1. Organic fertilizers were incorporated into the soil.

Table 1. Some physico-chemical properties of organic fertilizers.

	Rice husk compost (RHC)	Broad bean (B)	Turnip (T)
pH (1:10)	8.47	5.69	5.45
EC (dS m^{-1})	2.1	6.9	1.03
N (%)	0.064	0.214	0.151
Mg (ppm)	8468.55	2709.08	2516.38
Fe (ppm)	13548.10	254.93	412.50
Cu (ppm)	37.45	8.00	5.35
K (ppm)	11103.21	32277.05	28847.95
P (ppm)	16385.47	4654.94	2523.45
Ca (ppm)	40118.50	7526.58	9351.08
Mn (ppm)	936.35	32.85	21.58
Zn (ppm)	289.75	35.33	19.95

The broad bean seeds were planted (13 x 30 cm) in 1 m wide raised beds (three seeds in each plot) in the last week of November of both years. Broad beans were allowed to grow under natural conditions in open field. Broad bean green manure was incorporated into 20 cm depth of the soil (2 kg m^{-2}) at full flowering. The turnip seeds were sown in the last week of November of both years in a separate location. Then the obtained turnip residues were transported to the plots and fresh turnip leaves were incorporated into 20 cm depth of the soil (1 kg m^2). Rice husk compost was prepared on 30th of November of both years. The rice husk compost was prepared by the Indore method (Inckel *et al.*, 2005). According to this method, the heap was created using rice husk, grass, farmyard manure and soil. Rice husk was placed at the first layer (a layer of about 25 cm), grass was placed at the second layer (a layer of about 25 cm), and farmyard manure was placed at the third layer (a layer of 10 cm). This process was repeated four times to have a heap of 3.2 × 2.1 × 1 m. Finally, the top of the heap (a thin layer of 5 cm) was covered with soil (usually peat soil). Manure and soil ensures that the right micro-organisms were brought into the heap.

The rice husk was composted for 6 months, mixed and irrigated twice a week. Rice husk compost was incorporated into the upper 20 cm of the soil (9 kg m^{-2}) with a hoeing machine. Control plots were maintained without mulch and fertilizers.

Soil samples were taken from different parts of experimental plots at the first inflorescence and the last harvest of each growing season and soil nutrients, organic matter content, pH and EC values (Table 2) were determined according to methods specified in Kacar & İnal, (2008).

Seedlings were irrigated with double lines of drip tubes over raised beds (1 m width) and 15 mm water was supplied daily. Then the raised beds were covered with plastic mulch (1.3 m wide and 0.03 mm thick). When tomato seedlings had four true leaves, they were transplanted (2.96 plant m^{-2} with 50 cm row spacing and 45 cm on-row plant spacing) on 5th of June.

Temperature, humidity and light values during the growing season were measured using data recorders (KT100, Kimo, France). The values of light (PAR; MJ m^{-2} d^{-1}), humidity (%) and temperature (°C) are provided in Table 3 and Fig. 1. Green plastic net, used for commercial greenhouse shading with a light transmittance of 50% (Sarplast, Samsun, Turkey) was used for shading. The shading material was placed on 11th of June. Open-field shading material was attached 2.5 m above the galvanized wires. It was also pulled to cover the sides up to 40 cm.

Table 2. Soil analyses at the first inflorescence and the last harvest.

Years	Treatments	pH		EC (dS.m^{-1})		Ca (meq 100g^{-1})		Mg (meq 100 g^{-1})	
		First	Last	First	Last	First	Last	First	Last
1.	C	7.79	8.11	1.06	0.66	35.50	39.83	6.17	8.25
	RHC	7.76	7.92	1.43	0.91	35.79	39.75	11.96	9.17
	B	7.92	8.08	0.94	0.83	36.33	38.58	4.33	9.92
	T	7.93	8.05	1.03	0.77	40.08	38.92	18.17	9.75
2.	C	7.84	7.85	0.87	0.80	36.35	35.10	9.42	10.75
	RHC	7.54	7.61	1.40	0.86	29.94	33.13	12.50	11.36
	B	7.64	7.78	1.03	0.77	33.09	32.55	11.46	12.33
	T	7.78	7.79	0.91	0.94	34.40	34.61	9.24	10.12
		K (meq 100 g^{-1})		P (ppm)		OM (%)		Na (meq 100 g^{-1})	
1.	C	7.43	6.18	50.33	14.51	4.53	3.06	0.43	0.43
	RHC	11.82	10.02	100.45	51.43	5.99	5.19	0.56	0.59
	B	9.16	4.77	25.64	31.04	5.12	3.42	0.50	0.42
	T	7.30	5.45	34.61	18.62	4.17	3.45	0.42	0.37
2.	C	1.73	1.72	112.35	174.22	5.07	5.19	0.90	0.93
	RHC	5.37	4.38	315.74	188.61	12.96	8.24	1.28	1.00
	B	2.72	2.42	77.89	217.61	7.44	8.78	0.67	0.83
	T	1.93	1.94	180.10	199.07	4.33	7.36	0.77	0.77

*: RHC: rice husk compost; B: broad bean; T: turnip residues; C: control

Table 3. Humidity and temperature values of unshaded and shaded sections.

	Humidity (%)				Temperature (°C)			
	Unshaded		Shaded		Unshaded		Shaded	
	1. Year	2. Year	1. Year	2. Year	1. Year	2. Year	1. Year	2. Year
Min.	51	50	54.2	55	11.3	11.8	9,8	10.3
Max.	86.5	88	89.4	91.6	29.4	30	25.7	26.1
Mean	72	70.2	76	74	23.6	24.8	20.4	22

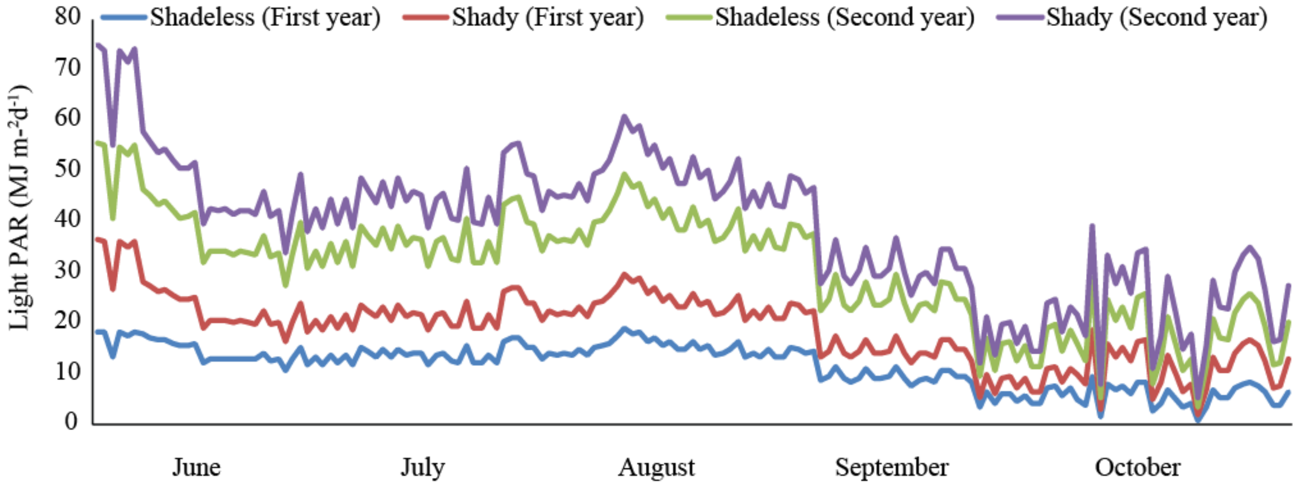


Fig. 1. Effects of shading on light intensity.

During the harvest period, pink-ripe fruits were harvested. Fruit weight was determined with a digital scale (± 0.01 g) (Precisa BJ 6100D, Dietikon, Switzerland). Yield was determined as fruit weight per plant (kg per plant). For each treatment, nine fruits were used to determine fruit firmness, soluble solids content, titratable acidity and vitamin C content. These measurements were made at the same time for all treatments in three different ripening periods (three fruits for each period). Fruit firmness (N) was measured on opposite sides of the peeled fruits using an Effegi penetrometer (4301, Instron, Massachusetts, USA) with 8 mm plunger (Kılıc *et al.*, 1991). Fruit firmness was measured as kg and was converted to newton (N). Soluble solids content was measured using a Carl-Zeiss Abbe refractometer (ATC-1, Atago, Japan). For titratable acidity, 5 mL sample of juice was diluted with 45 mL of distilled water and then titrated with NaOH (0.1 mol L^{-1}) and expressed as citric acid equivalents. Vitamin C content was determined with spectrophotometric (Pharmacia Novaspec II, Labexchange, Germany) procedure (Kılıc *et al.*, 1991). Mature tomato samples were kept in a refrigerator at 4°C for a day. Then they were thawed at room temperature and squeezed in hand to get fruit pulp. Five grams of pulp was supplemented with 50 mL of 0.4% oxalic acid solution. Spectrophotometric readings were made at 520 nm. The results were expressed as mg 100 g^{-1}.

Leaf stomatal conductance (mmol m^{-2} s^{-1}) was measured with a stomatal conductance device (SC-1, Decogon Devices, Pullman, USA) between the hours 11:00 and 12:00 a.m. Leaf chlorophyll content (CCI - Chlorophyll Content Index) was measured using a leaf chlorophyll meter (CCM-200, Opti-Sciences, Hudson, USA) between the hours 09:00 and 10:00 a.m. Photosynthesis rate (µmol O_2 m^{-2} s^{-1}) was measured using the photosynthesis device (PH1LP, Qubit System, Kingston, USA). These three measurements (leaf stomatal conductance, leaf chlorophyll content and photosynthesis rate) were performed on old, middle-aged and young leaves and the average was taken.

Experiments were conducted in randomized blocks split plots experimental design with three replications with 9 plants in each replication. Shading treatments were placed in blocks and fertilizer treatments were placed in plots. Resultant data were subjected to statistical analyses with SPSS 17.0 software (SPSS Inc, Chicago, USA). Differences between treatments were tested with Duncan's multiple range test at $p<0.01$.

Results and Discussion

Chemical properties and nutrient contents of organic fertilizers were quite different from each other. The highest nitrogen content (0.214%) was obtained from the broad bean green manure residue and the lowest value (0.064%) was obtained from rice husk compost (Table 1). The highest potassium content was obtained from the broad bean green manure residue. The rice husk compost residue had a higher calcium, magnesium, copper, iron, manganese and zinc contents than the broad bean green manure residue and turnip residue.

The stomata are very important organs for photosynthesis and leaf gas exchange and they are very important for the efficiency of crop plants (Taiz & Zeiger, 2008).Stomata movements are affected by many factors such as light intensity and quality, temperature and relative humidity. CO_2 concentration is another important factor for stomata movements. Increasing stomal conductance was reported with increasing light intensity (Casson & Gray, 2008). Similarly in present study, higher stomatal conductance was obtained from the unshaded treatments than the shaded ones (311 and 83.7 mmol $m^{-2}s^{-1}$, respectively) (Fig. 2).

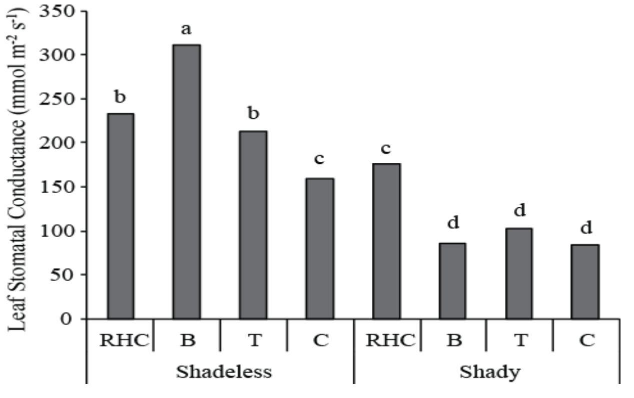


Fig. 2. Effects of different organic fertilizers (RHC; rice husk compost, B; broad bean green manure, T; turnip residues, C; control) and shading on leaf stomatal conductance (mmol m^{-2} s^{-1}) ($p<0.01$).

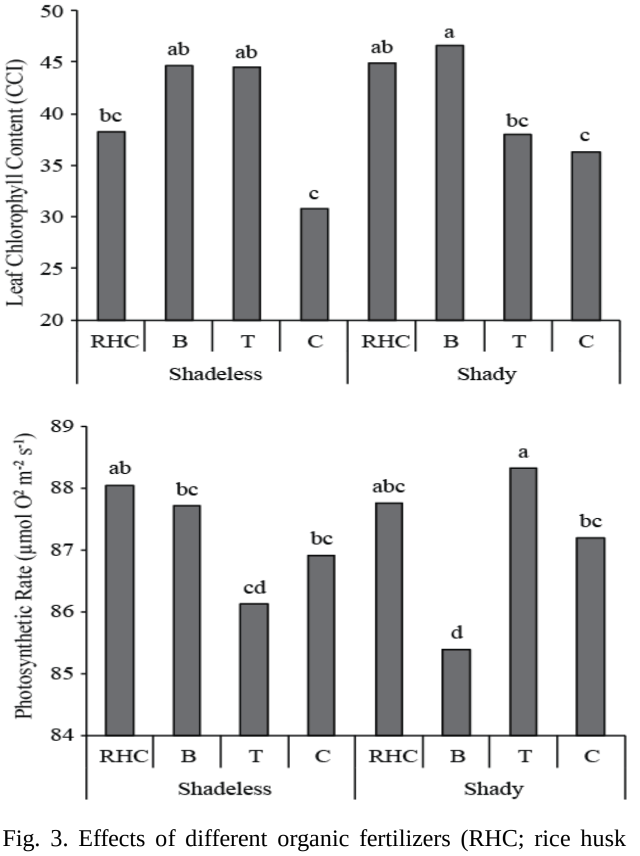


Fig. 3. Effects of different organic fertilizers (RHC; rice husk compost, B; broad bean green manure, T; turnip residues, C; control) and shading on leaf chlorophyll content (CCI) and photosynthetic rate (µmol O_2 m^{-2} s^{-1}) $p<0.01$).

The highest leaf chlorophyll contents (46.68 CCI) were obtained from the shaded broad bean green manure treatments. The lowest values were obtained from unshaded control treatments (30.82 CCI). Excessive light intensity also damages color pigments such as chlorophyll and carotenoids, which play an active role in photosynthesis (Taiz & Zeiger, 2008). In present study, it was observed that shading increased the leaf area, leaf elasticity and internodes but decreased leaf thickness. These findings were similar with the findings of Kılınç & Kutbay, (2008).

Significant variations were observed in leaf chlorophyll contents of shading and organic fertilizer treatments (Fig. 3). Chlorophyll contents are usually increased with the increase of N contents (Callistus & Anthony, 2014). Cimrin and Boysan (2006) reported a significant relationship between organic matter (OM) and N content. Similar findings were observed in present study. In general, treatments had significant effects on leaf chlorophyll content, organic matter (OM) and N content (Table 2; Fig. 3).

The greatest photosynthetic rate (88.31 µmol O_2 m^{-2} s^{-1}) was observed in shaded turnip (T) residue treatments. Temperature and light usually have significant effects on photosynthesis rate (Uzun, 2007;Taiz & Zeiger, 2008). In present study, shading decreased temperature (from 24.1 ^{o}C to 21.1 ^{o}C per day) and light intensity (from 14 to 8 MJ m^{-2} per day). It was observed that both shading and fertilizer treatments had significant effects on photosynthesis (Fig. 3).

The highest yields (3.9 and 3.3 kg per plant) were obtained from the shaded broad bean green manure and rice husk compost treatments (Fig. 4). In previous studies, increased tomato yields were reported with organic fertilizer treatments (Ceylan *et al.*, 2000; Okur *et al.*, 2007).Similar results were also reported for different plant species (Uysal, 2005; Elgin *et al.*, 2006; Duyar *et al.*, 2008; Özer & Uzun, 2013; Duyar, 2014). Soil nutrient contents increased with organic fertilizers (Table 2), thus increasing yields (kg per plant) were observed with organic fertilizers (Fig. 4).

Previous studies reported increased yields with increasing light intensity and temperature but indicated a stress exerted through excessive light intensity. Besides other conditions, plant-water relations should also be well-adjusted for a successful vegetable growing. Stomatal conductance, which is affected by plant-water relationships, plays an important role in photosynthesis (Dickison, 2000; Elad *et al.*, 2007; Casson & Gray, 2008; Kılınç & Kutbay, 2008; Taiz & Zeiger, 2008; Shamim *et al.*, 2015). Effects of shading on yield were quite remarkable in broad bean treatments (Fig. 4). Shading (50%) increased the yield per plant by 13% (Fig. 4). Similar yield increases with shading were also reported by Söylemez *et al*. (2008).

Shading extended the harvest period (stay-green durations) (Table 4). The highest yield was obtained from the broad bean treatments (3.9 kg $plant^{-1}$) with the longest stay-green durations in shaded sites.

Tomato fruit firmness values varied between 19.6 - 14.7 N (Fig. 5).The highest fruit firmness (19.62 N) was observed in turnip residue treatments and the lowest fruit firmness (14.7 N) was found in control and unshaded broad bean green manure treatments. The firmness was not influenced by shading (shaded and unshaded) and fertilization (rice husk compost, broad bean green manure and turnip residues) treatments. But, it was observed that firmness was decreased with unshaded broad been green manure (Fig. 5). The average of shading (50% shaded and unshaded) treatments increased fruit firmness (15.94 to 17.16) with shading. Similar results were also reported by Ilic *et al.* (2014) indicating higher fruit firmness values under colored shade-nets. Fruit firmness is an important quality parameter for tomatoes (Thybo *et al.*, 2006; Vursavuş *et al.*, 2015).

Table 4. Effects of shading and organic fertilizers on harvest period (number of days) (p<0.01).

Treatments		Harvest period (days)		
		First harvest	Last harvest	Duration of harvest
Unshaded	RHC	74.57 **bc***	158.22 **a**	83.64 **b**
	B	73.80 **c**	161.53 **a**	87.73 **a**
	T	76.25 **b**	154.39 **ab**	78.13 **bc**
	C	80.89 **a**	143.75 **c**	62.86 **c**
Shaded	RHC	73.98 **c**	156.91 **ab**	82.93 **b**
	B	69.72 **d**	162.17 **a**	92.43 **a**
	T	73.25 **c**	155.15 **ab**	81.89 **b**
	C	79.56 **a**	129.50 **d**	49.94 **d**

Means with different letters in the same column were significantly different *p<0.01

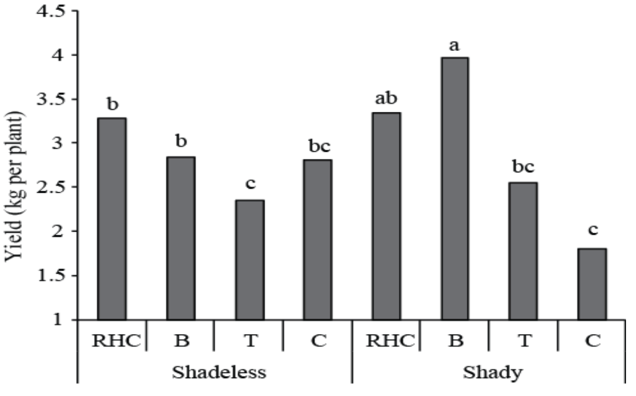


Fig. 4. Effects of different organic fertilizers (RHC; rice husk compost, B; broad bean green manure, T; turnip residues, C; control) and shading on yield (kg per plant) (p<0.01).

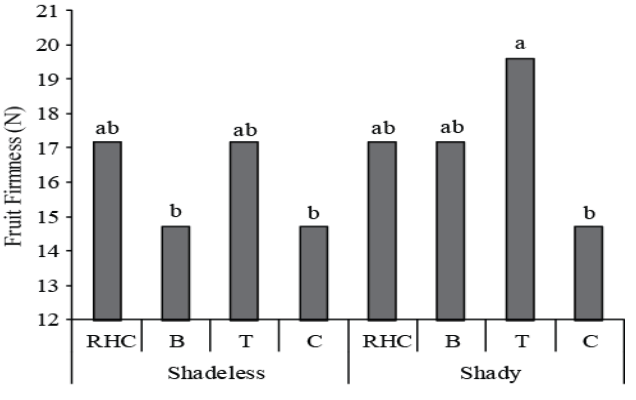
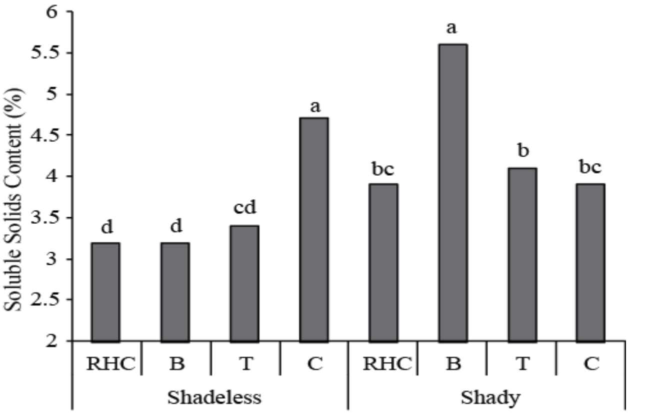
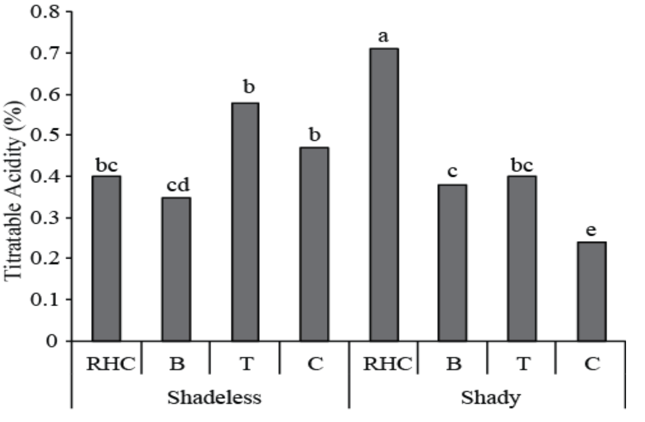


Fig. 5. Effects of different organic fertilizers (RHC; rice husk compost, B; broad bean green manure, T; turnip residues, C; control) and shading on fruit firmness (N) (p<0.01).

Soluble solids contents (SSC) ranged from 3.2 to 5.6 % (Fig. 6). Previous researchers also reported similar findings (varied between 2.90-4.70%) for tomatoes (Karataş *et al.,* 2005; Ünlü & Padem, 2009). The SSC is an important factor in shading treatments. The lowest SSC (3.2%) was obtained from unshaded rice husk compost, broad been green manure and turnip residue treatments (Fig. 6). In a previous research, it was reported that shading levels had significant effects on sucrose and glucose levels (Watson *et al.,* 2002; Söylemez *et al.,* 2008).





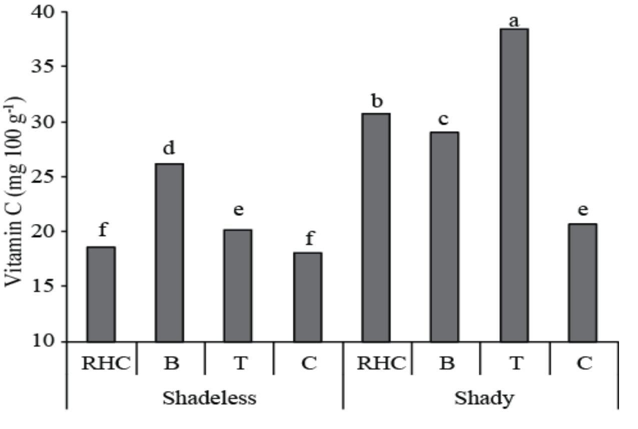


Fig. 6. Effects of different organic fertilizers (RHC; rice husk compost, B; broad bean green manure, T; turnip residues, C; control) and shading on soluble solids content (%), titratable acidity (%) and vitamin C (mg 100 g^{-1}) content (p<0.01).

Titratable acidity values ranged from 0.24 to 0.71%. Current findings were similar to previous results (varied between 0.23-0.83 %) reported for tomatoes (Thybo *et al.,* 2006; Toor *et al.,* 2006; Ünlü & Padem, 2009; Ilic *et al.,* 2014). Ilic e*t al.* (2014) reported that fruit quality was characterized by titratable acidity and indicated increased values with high air temperatures. However, in present study, titratable acidity was increased with shaded rice husk compost treatments. Reduction of sugar transport with shading caused an increase in acidity. Aloni *et al.* (1994) noted that reduction of irradiation intensity decreased sugar transport to flowers buds. Shading had a higher effect than temperature on titratable acidity. However, the effect of shading on acidity was not clear in present experiments.

Vitamin C contents in the present study varied between 18.14-38.44 mg 100 g^{-1}. Under shading conditions, while the vitamin C content was maximum in turnip waste treatment, the value was minimum in control treatment (Fig. 6). In a previous study, vitamin C contents were reported between 15-23 mg 100 g^{-1} (Ünlü & Padem, 2009).Researchers usually reported increasing vitamin C contents with increasing sunlight (Lee and Kader, 2000; Ercan, 2002). But, there is a saturation point in light intensity of the leaves. Optimal light intensity for tomato cultivation was between 6 and 8 MJ m^{-2} d^{-1} (Uzun, 2007).In present study, light intensity was recorded as 8 MJ m^{-2} d^{-1} in 50% shading and as 14 MJ m^{-2} d^{-1} in unshaded sections (Fig. 1). Shading increased vitamin C content and the greatest vitamin C content was observed in shading treatments (Fig. 6). It was also reported that organic fertilizer treatments significantly influenced vitamin C contents (Ceylan *et al.*, 2000; Uysal, 2005). Ercan (2002) reported that, while potassium and manganese fertilizers increased vitamin C contents, excessive nitrogen fertilization, particularly under higher light conditions, reduced vitamin C contents. Parallel to previous findings, vitamin C contents were decreased with increasing organic fertilizers in the present study (Fig. 6, Table 2).

Conclusions

Organic fertilizers had significant effects on yield and qualityparameters of tomatoes. In terms of the parameters evaluated, broad been green manure (B) and rice husk compost (RHC) treatments were considered as suitable organic fertilizers for tomato quality and yield.

Present findings also revealed that shading (50%) treatments had significant effects on photosynthetic rate, stomatal conductance and leaf chlorophyll content. Such positive effects of shading on yields were probably resulted from improved stay-green durations of the plants.

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