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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Effects of Chemical and Organic Fertilizer Treatments on Yield and Quality Traits of Industrial Tomato

Kimyasal ve Organik Gübre Uygulamalarının Sanayi Domatesinin Verim ve Kalite Özellikleri Üzerine Etkileri

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Abstract

Increasing plant production by protecting the environment is one of the main goals of today's agriculture. On the other hand, the use of both inorganic and organic fertilizers is becoming increasingly extensive. This study was carried out in field conditions to determine the effects of organic and inorganic fertilization on yield and quality characteristics of industrial tomato (*Solanum lycopersicum* L., cv. Heinz 1015 F_1). For this purpose, contents of fruit total soluble solid contents, total dry matter, titratable acidity, lycopene, total carotenoids, and vitamin C contents and yield (marketable yield and paste yield) were determined. Experiments were conducted in randomized blocks design with 3 replications. There were seven experimental treatments as of control (without fertilizer), chemical fertilizer, organic farmyard manure, sheep manure, poultry manure, vermicompost and leonardite. According to the research results, the highest marketable and tomato paste yield were obtained from chemical fertilizer, followed by organic fertilizers and the lowest values were obtained from the control. As compared to chemical fertilizers, organic fertilizers influenced fruit quality attributes more positively. The highest lycopene, total carotenoid and vitamin C contents were obtained from organic fertilizers, especially from poultry manure. Fruit soluble solids and dry matter contents, important processing traits assumed by tomato industry, were obtained from poultry manure treatments. Fruits from leonardite-treated plants had considerably higher titratable acidity levels. Except for total dry matter and titratable acidity, lowest values of quality parameters considered important in industrial tomatoes were obtained from unfertilized (control) plots. Present findings revealed that chemical fertilizers were essential for high and economic yield levels in tomato farming, but organic fertilizers should also be supplemented to improve tomato fruit quality attributes.

Keywords: Yield, Quality, Organic fertilizers, Chemical fertilizers, Tomato

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Özet

Çevreyi koruyarak bitkisel üretimi artırmak günümüz tarımının ana hedeflerinden birisidir. Diğer yandan, inorganik ve organik gübrelerin kullanımı giderek artmaktadır. Bu çalışma organik ve inorganik gübrelemenin domatesin (*Solanum lycopersicum* L., cv. Heinz 1015 F_1) verim ve kalite özelliklerine etkisini belirlemek amacıyla tarla koşullarında gerçekleştirilmiştir. Bu amaçla domates meyvesinde toplam suda çözülebilir kuru madde, toplam kuru madde, titre edilebilir asitlik, likopen, toplam karotenoid ve C vitamin içerikleri ile verim (pazarlanabilir meyve ve salça verimi) belirlenmiştir. Deneme tesadüf blokları deneme desenine uygun olarak, 3 tekrarlamalı olarak planlanmış ve domates bitkilerine kontrol (gübre uygulanmayan), kimyasal gübre, organik çiftlik gübresi, koyun gübresi, tavuk gübresi, solucan gübresi ve leonardit olmak üzere yedi farklı gübre uygulaması yapılmıştır. Araştırma sonuçlarına göre, domateste en yüksek pazarlanabilir meyve verimi ve salça verimi kimyasal gübrelemeden elde edilirken, bunu organik gübreler izlemiş ve en düşük verim değerleri kontrol uygulamalarından elde edilmiştir. Organik gübrelerin kullanımı, meyve kalite özelliklerini kimyasal gübrelere göre daha olumlu etkilemiştir. En yüksek meyve likopen, toplam karotenoid ve C vitamin içerikleri organik gübrelerden, özellikle tavuk gübresinden elde edilmiştir. Domates işleme endüstrisi için önemli sayılan meyvede suda çözünebilir katılar ve kuru madde içerikleri bakımından en yüksek değerler tavuk gübresinde bulunmuştur. Leonardit uygulanmış domateslerde titre edilebilir asitlik önemli derecede yüksektir. Diğer taraftan sanayi domateslerinde kalite özellikleri (toplam kuru madde ve titre edilebilir asitlik hariç) en düşük meyveler, gübre uygulanmayan domates bitkilerinden elde edilmiştir. Araştırma sonuçları verimli ve ekonomik domates yetiştiriciliği için kimyasal gübrelerin gerekli olduğunu, aynı zamanda domates meyve kalitesini arttırmak için de organik gübrelerin kullanılması gerektiğini göstermiştir.

Anahtar Kelimeler: Verim, Kalite, Organik gübreler, Kimyasal gübreler, Domates

1. Introduction

Fertilizers implicate substances applied to soil to supply essential chemicals required for plant growth and development (Ulusu and Yavuzaslanoğlu, 2015). Insufficient fertilizations result in serious losses in yield and quality. On the other hand, excessive applications result in nitrogen and phosphorus leaching into ground waters and then into surface waters through groundwater flows and consequently water pollution. Nitrous oxide emissions also generate air pollution (Güler, 2004).

Plant growth and yield largely depend on quality and quantity of fertilizers (Chang et al., 2010). Fertilizers are classified into two broad groups as of inorganic and organic. Organic fertilizers are generally obtained from plant and animal wastes or minerals, thus they are renewable and soluble in nature and therefore they are sustainable and environment-friendly substances. Organic fertilizers improve soil structure and increase water and nutrient holding capacity of the soils (Ulusu and Yavuzaslanoğlu, 2015). As it was in inorganic fertilizers, organic fertilizers not only the improve plant growth and development through meeting plant nutrient requirements, but also suppress pest populations (Bulluck and Ristaino, 2002). Nileemas and Sreenivasa (2011) reported that organic fertilizer treatments increased soil microbial activity and improved availability of nutrients for tomatoes. Edmeades (2003) reported that organic fertilizers (sheep, cattle manure and poultry litter and green fertilizers) improved organic matter accumulation and soil N, P, K, Ca and Mg contents.

Schnitzer and Khan (1972) indicated that humic compounds improved plant nutrient uptake from the soils, soil water holding capacity, loosened soil structure and improved soil aeration. Humic substances are primary constituents of leonardite and can be classified into humic acid and fulvic acid. Leonardite is rich in organic matter (50-75%) and its humic acid content varies between 30-80% (Akinremi et al., 2000). İstanbulluoğlu (2012) defined that leonardite as an organic substance not fully carbonized like coal and rich in humic acid, organic carbon, macro and micronutrients. Demirkıran et al. (2012) indicated that leonardite could efficiently be used as a fertilizer in organic tomato farming. Vermicompost treatments had positive effects also on soil physical characteristics, increased aggregate stability and decreased bulk density of the soils (Aktaş and Yüksel, 2020). It was reported in previous studies that humic compounds, including humic acid, improve plant root and shoot growth and development and nutrient uptake and enhance plant resistance to biotic and abiotic stress factors (Akinremi et al., 2000; Dursun et al., 2002; Serenella et al., 2002; Cimrin and Yılmaz, 2005; Unlu et al., 2010).

Chemical and organic fertilizers may have both positive and negative impacts on plant growth and development and soil structure. Chemical fertilizers are relatively cheaper, easy to use, contain high quantity of nutrients and they can easily be up taken by the plants. On the other hand, excessive use of chemical fertilizers results in soil degradation, ground and surface water pollution through nutrient leaching into these sources, soil acidity or alkalinity, reduction in beneficial microbial populations, increase plant sensitivity against the pests. Chemical fertilizers also pose some risks on environment, human and animal health (Chen 2006; Mahmood et al., 2017). Therefore, organic fertilizers are started to be used in agricultural practices as an alternative to chemical fertilizers (Ece et al., 2007).

Tomato is one of the most important fruit crops grown throughout the world (Atkinson et al., 2011). Tomato is consumed in different forms including bulk paste, puree, ketchup, tomato juice, fresh and dry tomato. In 2019, 4.005.935 tons industrial tomato was produced in Turkey. Bursa province with an annual production of 1.152.974 tons is the leading industrial tomato producing province of Turkey (TUIK, 2019). It is quite significant to search for whether organic or inorganic fertilizers are to be used in industrial tomato cultivation, or a mid-way should be found between two types of fertilizers. Therefore, this study was conducted to investigate the effects of organic and inorganic fertilizers on industrial tomato yield and quality attributes influencing tomato paste quality.

2. Materials and Methods

2.1. Plant material and experimental site

Field experiments were conducted in summer growing season (May-August) of 2019 over the experimental fields of Mustafakemalpaşa Vocational School of Bursa Uludağ University (40°02′ N, 28°23′ E., altitude 22 m). “Heinz-1015” industrial hybrid tomato (*Solanum lycopersicum* L.) cultivar, commonly used in commercial tomato farming of Turkey, was used as the plant material of the experiments. Tomato seedlings were supplied from a commercial seedling company (Marmara Seedling Product. Agri. Industry Trade Ltd. Co. Bursa, Turkey).

Experimental soils were clay-loam in texture, unsaline (0.49 dS m^{-1}) with slightly alkaline reaction (pH=7.9) and high lime content (11.9%). Soils were rich in available potassium (283.0 mg kg^{-1}), low in phosphorus (11.8 mg kg^{-1}), poor in organic matter (2%), moderate in total nitrogen (0.17%), and sufficient in zinc (0.71 mg kg^{-1}). Summers are hot and dry and winters are rainy in the region. Long-average climate data (1928 – 2018) and climate data for the tomato growing season of the region (May-August 2019) are provided in *Table 1*.

Table 1. Climatic data in long-time averages and averages for the months of the study

	Precipitation (mm)		Relative humidity (%)		Mean temperature ºC	
Months	2019	1928-2018	2019	1928-2018	2019	1928-2018
May	52	43.4	72	62	19.7	17.7
June	37	36.5	64	58	24.4	22.1
July	35	17.7	65	56	24.5	24.5
August	26	13.8	64	57	25.1	24.3

2.2. Agronomic practices

The experimental design consisted of randomized complete blocks with three replicates. Each replicate had 20 plants. About 1.5 m spacing was provided between the plots. Two extra rows were placed around each plot as to consider side effects. Treatments were randomly assigned to each plot. Tomato seedlings were planted in the field with 35cm between plants within rows x 140 cm between rows spacing on 7th of May. Herbicide was not applied and weed control was practiced with manual hoeing. Standard cultural practices were applied throughout the growing season. Plants were irrigated with drip irrigation method and irrigation water was supplied from groundwater.

Six different fertilizers (5 organic fertilizers and one chemical fertilizer) were applied to tomato plants. Fertilizers were not applied to control plots (T_0). Chemical fertilizer (T_1) was applied to experimental plots at soil tillage. As base fertilization P_2O_5 80 kg ha^{-1}, K_20 50 kg ha^{-1} and 75 kg ha^{-1} N were applied before sowing and additional N 75 kg ha^{-1} was applied at small-fruit stage (Şalk et al., 2008). The source used were triple super phosphate, potassium sulphate and ammonium sulfate. All organic fertilizer treatments; organic farmyard manure (T_2), sheep manure (T_3), poultry manure (T_4), vermicompost (T_5) and leonardite (T_6) were performed three weeks before planting as 30 t ha^{-1}. In this study, the applied quantities of organic fertilizers were based on usual application by local farmers (Mohammad et al., 2013).

Organic fertilizers were supplied from a commercial supplier. Some characteristics of organic fertilizers are provided in *Table 2*.

Table 2. Some physical and chemical properties of organic manures used in the experiment

Treatments	Organic matter (%)	C/N	Moisture (%)	pH	N (%)	P (%)	K (%)
Organic Farm Manure	50	12.0	20	7.0-8.0	2.50	2.50	2.50
Sheep Manure	53	19.0	35	6.7	1.55	0.57	1.58
Poultry manure	65	4.9	15	5.5-7.5	4.00	2.00	2.00
Vermicompost	30-50	12.8	25-35	7.0-9.0	2.50	2.00	2.50
Leonardite	40	17.0	35	5.8-7.8	1.79	0.24	1.35

2.3. Harvest and Analyses

Tomato fruits were harvested at full-red stage between 26 July – 15 August in 6 harvests. Fruits were picked when totally ripe and classified as marketable or non-marketable (fruits with mechanical, physiologic and/or phytosanitary damages) (Campos et al., 2006). Marketable fruits were weighed after each harvest and marketable yield t ha^{-1} was calculated by taking 1.40 x 0.35m spacing into consideration. For paste yield (PY, t ha^{-1}); harvested tomato fruits were washed, scrapped, chopped and heated up to 85-90 ºC (heated processing method), passed through pulper. Resultant pulp was evaporated in open caldrons until soluble solids dry matter of 28% (28^0Brix) (Cemeroğlu et al., 2003).

For analyses, 10 fruits were randomly selected from each plot after each harvest. Selected fruits were washed through tap water, and then rinsed through distilled water. Cleaned fruits were deseeded and ground. Ground samples were dried in an oven at 70 °C for 48 hours and weighed to get dry matter (DM, %) contents. Soluble solid contents (SSC) were determined in a refractometer (Abbe-type refractometer, model 60/Direct Reading, Bellington and Stanley Inc., Kent, UK) directly with the use of fruit juice and results were expressed in °Brix at 20 °C. Titratable acidity (TA) content was determined by titration with 0.1 N sodium hydroxide (NaOH), using phenolphthalein as an indicator and results were expressed in % citric acid (Soare et al., 2018). The lycopene and total carotenoid contents were determined by petroleum ether-acetone extraction and measured at the wavelength of 452 and 472 nm using a spectrophotometer (Shimadzu UV-1208, Shimadzu Co., Kyoto, Japan) (Adsule and Dan, 1979; Tepic et al., 2006). Lycopene and carotene contents were expressed in mg 100 g^{-1}. Vitamin C (ascorbic acid) (mg 100 g^{-1}) content was determined by indicator of homogenate fresh samples (AOAC, 1980).

2.4. Statistical analyses

Experimental data were subjected to analysis of variance with SPSS software (IBM® SPSS® Statistics for Windows, Version 20.0, Copyright, 2011, IBM Corp, Armonk, NY). Significant means were compared with the use of Duncan's multiple range tests.

3. Results and Discussion

Effects of chemical and organic fertilizer treatments on marketable yield were found to be significant (Table 3). The highest yield (70.22 t ha^{-1}) was obtained from chemical fertilizer treatment and the lowest yield (15.24 t ha^{-1}) was obtained from the control treatments (no fertilizer application). Organic fertilizer treatments had greater yields than the control, but lower than the chemical fertilizer treatments. Considering the effects of treatments on yield, experimental treatments sorted by Duncan groups were ordered as; $T_1 > T_4 > T_3 > T_5 \geq T_2 > T_6 > T_0$. Complying with the present findings, Mahmood et al. (2017) indicated that high chemical fertilizer quantities increased yields in intensive production systems. Heeb et al. (2006) indicated limited effects of organic fertilizers on plant growth and yield as compared to chemical fertilizers. Such limited effects of organic fertilizers were attributed to slower release of nutrients from the organic fertilizers than from the chemical fertilizers and reductions in leaf S, P and N concentrations. Okur et al. (2007) reported that organic fertilizers improved soil fertility through accelerated microbial activity. In this study, among the organic fertilizers, poultry manure was remarkable with a yield level of 60.05 t ha^{-1}. Masarirambi et al. (2010) and Rees and Castle (2002) also pointed out the significance of poultry manure and reported higher yields from poultry manure treatments as compared to the other organic fertilizers.

Effects of different fertilizer treatments on tomato paste yield varied based on source of fertilizer (*Table 3*). Both chemical and organic fertilizer treatments had positive effects on tomato paste yields. The lowest tomato paste yield (2.90 t ha^{-1}) was obtained from the control treatments and the greatest tomato paste yield (14.55 t ha^{-1}) was obtained from chemical fertilizer treatments followed by organic fertilizers. Among the organic fertilizers, poultry manure produced significant increase in tomato paste yield (13.29 t ha^{-1}). In terms of paste yield all treatments can be arranged in decreasing order as follows: $T_1 > T_4 > T_3 > T_5 \geq T_2 > T_6 > T_0$.

Table 3. Effects of chemical and organic fertilizer applications on paste and marketable fruit yield and fruit quality characters

Treatments	MY	PY	TSSC	DM	TA	Lycopene	Carotenoids	Vitamin C
(T)	(t ha^{-1})		(^{0}Brix)	(%)		(mg 100g^{-1})		
T_0	15.24 f	2.90 f	5.41 c	6.44 ab	0.48 ab	5.93 f	6.94 f	20.42 d
T_1	70.22 a	14.55 a	5.80 b	6.11 bc	0.48 ab	7.14 e	8.21 e	26.31 b
T_2	51.41 d	10.36 d	5.65 bc	6.02 c	0.46 a-c	7.46 c	9.50 c	26.99 b
T_3	57.60 c	11.83 c	5.75 bc	6.34 a-c	0.41 cd	7.90 a	9.94 a	22.59 c
T_4	60.05 b	13.29 b	6.20 a	6.68 a	0.43 bc	7.92 a	9.98 a	29.06 a
T_5	52.10 d	10.25 d	5.51 bc	6.18 bc	0.37 d	7.79 b	9.73 b	23.45 c
T_6	46.89 e	9.21 e	5.50 bc	5.65 d	0.50 a	7.26 d	8.67 d	22.34 cd

As: T_0 control "no fertilizer application", T_1 chemical fertilizer, T_2 organic farm manure, T_3 sheep manure, T_4 poultry manure, T_5 vermicompost, T_6 leonardite, MY marketable yield, PY paste yield, SSC soluble solid content, DM dry matter, TA titratable acidity

Chemical and organic fertilizers were applied to soil to investigate the effects of experimental treatments on fruit quality traits of tomato and results are provided in Table 3. According to variance analysis, effects of experimental treatments on soluble solids content were found to be significant. The highest soluble solid contents were obtained from poultry manure-treated fruits (6.20). Such a finding complies with the results of earlier studies conducted on tomatoes (Chassy et al., 2006; Barrett et al., 2007; Rickman and Barrett, 2008; Bilalis et al., 2018). Positive effects of poultry manure treatments on fruit quality of Sadia F_1 and Sun cherry tomato cultivars were reported by Kalbani et al. (2016). Alternatively soluble solid contents were the lowest in control plants (5.41) while chemical fertilizer resulted in second highest soluble solid contents, farmyard manure, sheep manure, vermicompost and leonardite treatments yielded closer soluble solid contents to each other. However, the use of vermicompost is very important for sustainable agriculture (Bellitürk et al., 2020).

Cemeroğlu (2011) indicated that processing tomatoes should have certain quality attributes, and Yıldız (2004) pointed out the processing tomatoes should have high dry matter contents. Dry matter contents of tomato fruits were significantly influenced by the experimental treatments (Table 3). The greatest dry matter content (6.68%) was obtained from poultry manure-treated plants. Dry matter contents slightly decreased in sheep manure and chemical treatments and the lowest dry matter content (5.65%) was obtained from leonardite treatments. Effects of experimental treatment on dry matter contents were ordered as; $T_4 > T_0 > T_3 > T_5 \geq T_1 > T_2 > T_6$.

The greatest titratable acidity (0.50%) was obtained from leonardite treatments and the lowest titratable acidity (0.37%) was obtained from vermicompost treatments (Table 3). Control, chemical fertilizer and farmyard manure treatments also had high fruit acidity values and these treatments were respectively followed by sheep manure and poultry manure treatments. Bilalis et al. (2018) indicated titratable acidity as an important quality criterion for processing tomatoes. Barrett et al. (2007) reported greater titratable acidity values for organically grown tomatoes.

Since fruit color directly influence tomato paste color, it is considered as a significant quality criterion. Lycopene is responsible of fruit red color. High lycopene and total carotenoid contents are desired by tomato processing industry since high levels of both parameters increase the quality and antioxidant content of tomato paste (DePascale et al., 2001; Marković et al., 2006; Lambelet et al., 2009). In present study, significant differences were observed in fruit lycopene and total carotenoid contents of experimental treatments (Table 3). Organic fertilizer treatments resulted in superior data in comparison to the control and inorganic fertilizer application. Among the organic fertilizers, poultry and sheep manure treatments yielded the highest lycopene (7.92 and 7.90 mg L^{-1}, respectively) and carotenoid (9.98 and 9.94 mg L^{-1}, respectively) contents. Alternatively the lowest lycopene and carotene (5.93 and 6.94 mg L^{-1}, respectively) contents were obtained from the control treatments without any fertilizers.

Variance analysis revealed that experimental treatments had positive effects on fruit vitamin C contents (Table 3). As compared to the control, both inorganic and organic fertilizers significantly increased vitamin C contents. The greatest vitamin C content (29.06 mg 100g^{-1}) was obtained from poultry manure treatments followed by organic farmyard manure, chemical fertilizer, vermicompost, sheep manure and leonardite treatments, respectively. In previous studies, better taste, greater vitamin C contents and other compound levels were reported for organically grown fruits. Organic tomatoes had greater vitamin and mineral contents than conventionally-grown ones (Akıllı and Cücü, 1996). On the other hand, Uçurum (2012) reported insignificant differences between organically and conventionally-grown tomatoes (cv. Rio Grande).

4. Conclusions

The highest marketable yield and tomato paste yields were obtained from chemical fertilizer treatments. Organic fertilizers significantly increased yield components related to control, but they were not as much effective as the chemical fertilizers. Among the organic fertilizers, poultry manure had greater yields than the other organic fertilizers. Marketable yield and tomato paste yield were found to be substantially lower in control treatments. Such a finding revealed that fertilization was essential for high and economic yields in tomato.

Fruit quality attributes are significant in tomato processing industry since fruit quality directly reflects on quality of processed product. In respect of quality parameters, organic fertilizers, especially poultry manure treatments, were found to be more effective. The lowest values of quality parameters were observed in unfertilized plants (control). Such findings are further supported the significance of fertilization in tomato growing. It was concluded, based on present findings that use of organic fertilizers gave superior results in fruit quality and have positive effects on yield of processing tomato.

While determining the amount of organic fertilizer used in our study, an average of 30 tons of ha was applied, taking into account the information obtained from local farmers. This made the application more natural and allowed organic fertilizers to be compared among themselves. In future studies, when deciding on the amount of organic fertilizer to be applied, farmer applications and the amount of NPK that will be brought into the soil by organic fertilizers should also are taken into consideration.

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