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Effects of Farm Manure, Vermicompost and Plant Growth Regulators on Yield and Fruit Quality in Watermelon

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ABSTRACT
This study was conducted in 2018, under open field conditions in Adıyaman Province of Turkey to determine the effects of farm manure, vermicompost and plant growth regulators on yield and some fruit quality parameter of watermelon. Matured farm manure, vermicompost and three different plant growth regulators (Crop-Set, Endoroots and ISR-2000) were used to compare with control (not fertilizers applied) application. Vermicompost, farm manure, Endoroots, ISR-2000 and Crop-Set were applied to the plants at 150 kg, 2 tons, 250 g, 60 cc and 90 cc da-1 doses, respectively. The highest yield result was obtained from Endoroots application (11.630 tons da^{-1}). Fruit weight varied between 2.93 (control) kg and 5.01 kg (vermicompost). Higher results were observed from vermicompost application for fruit weight, fruit width, fruit height, phenolic. Total Soluble Solids (TSS) was recorded statistically significant for Endoroots application. Applied plant growth regulators, farm manure and vermicompost fertilizers had significant effects on pomological and phenological characteristics of watermelon under semi-arid conditions. The highest results have been determined from Endoroots and vermicompost applications. As a result of this study, Endoroots (250 g da^{-1}) and vermicompost (150 kg da^{-1}) fertilizers can be concluded as a beneficial application for watermelon cultivation.

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Çiftlik Gübresi, Vermikompost ve Bitki Büyüme Düzenleyicilerinin Karpuz Meyvesinde Verim ve Meyve Kaliteye Etkileri

ÖZET
Bu çalışma, 2018 yılında Türkiye'nin Adıyaman ilinde açık alan koşullarında organik gübrelerin ve bitki büyüme düzenleyicilerinin karpuzun verim ve bazı meyve kalitesi parametrelerine etkilerini belirlemek amacıyla yapılmıştır. Kontrol (hiç uygulama yapılmayan) ile karşılaştırmak için çiftlik gübresi, vermikompost ve üç farklı bitki büyüme düzenleyicileri (Crop-Set, Endoroots ve ISR-2000) kullanılmıştır. Vermikompost, çiftlik gübresi, endoroots, ISR-2000 ve Crop-Set sırasıyla150 kg, 2 tons, 250 g, 60 cc ve 90 cc da^{-1} dozları olacak şekilde bitkilere uygulanmıştır. En yüksek verim (11.630 ton da-1) sonucu Endoroots uygulamasından elde edilmiştir Meyve ağırlığı 2,93 kg (control) ile 5,01(vermicompost) kg arasında değişmektedir. Meyve ağırlığı, meyve genişliği, meyve yüksekliği, fenolik için vermikompost uygulamasından daha yüksek sonuçlar elde edilmiştir. Suda Çözünebilir Kuru Madde Miktarı (SÇKM) Endoroots uygulaması için istatistiksel olarak anlamlı bulunmuştur. Uygulanan bitki büyüme düzenleyicileri, çiftlik gübresi ve vermikompostun, yarı kurak koşullar altında karpuzun pomolojik ve fenolojik özellikleri üzerinde önemli etkileri olmuştur. En yüksek sonuçlar Endoroots ve vermicompost uygulamalarından belirlenmiştir. Bu çalışmanın sonucunda, Endoroots (278 g da-1) ve vermikompost (150 kg da-1) gübreleri, karpuz yetiştiriciliği için faydalı uygulamalar olarak sunulmaktadır.

Araştırma Makalesi

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INTRODUCTION

Plant growth regulator isolated from the root zone of different crops. They have effects on plant growth and improvement of nutrient uptake (Çakmakçı et.al, 2006). The use of Plant Growth Promoting Bacterias (PGPRs') as bio-fertilizers or bio-control agents in agriculture has been a focus of research for a number of years. Plant growth regulators constitute a natural defense system of plants and ensure the nutrient uptake. They also help to protect plants against external factors and affect their yield and product quality positively (Iwata, 2001).

PGPR can help plants to grow in nutrient deficient conditions. Additionally, they were characterized as salt tolerant and temperature resistant in a study conducted in Uzbekistan (Egamberdiyeva and Höflich, 2004). The effect of PGPRs on sour cherry cultivation, suggested that *Bacillus* T8 and *Bacillus* OSU-142, alone or in combination, have a great potential for the enhancement of yield and plant growth of sour cherry and therefore they have been suggested in growth promotion in sour cherry cultivation (Arıkan and Pırlak, 2016). From these results we conclude that plant growth regulators may be isolated from the soil of different crop root zones.

The effects of different kinds of organic fertilizer on the growth, yield, quality, and nutrient absorption and utilization of watermelon were examined to provide theoretical basis for adequate fertilization and efficient production of watermelon in gravel-mulched field (Ouda and Mahadeen, 2008). In another study, suggested that effects of mineral and organic fertilization in the plant development, nutritional status, and fruit yield of melon (De Souza et al., 2018). Organic fertilizers contain nitrogen (N), phosphorus (P), potassium (K) and other nutrients in different proportions. In addition to providing nutrients, they also help growing plants and physical, chemical and biological characteristics of soil (Aygün and Acar, 2019). The application of bovine manure resulted in increase of nitrogen organic forms in soil (De Souza et al., 2018).

This study was focused on which fertilizers can be used on watermelon cultivation under semi-arid climatic conditions also according to results fertilization program of watermelon can be prescribed. This study to determine the effects of organic fertilizers and plant growth regulators on yield and some fruit quality parameters (pomological criteria, antioxidant, lycopene, phenolic and total chlorophyll) in watermelon cultivation.

MATERIALS and METHODS

The experiment was carried out in Adıyaman University Agricultural Research Center Application Area (ADYÜTAYAM) in 2018. Some soil physical and chemical properties of experimental area are given in Table 1.

Table 1. Some Soil Physical and Chemical Properties of the Experimental Area
Çizelge 1. Deneme Alanına Ait Bazı Fiziksel ve Kimyasal Toprak Özellikleri

Soil Properties *Toprak Özellikleri*	Depth (cm) *Derinlik (cm)* 0-30 cm (*0-30 cm*)	30-60 cm (*30-60 cm*)	References (*Referanslar*)
Texture	clay	sand-clay	Bouyocous (1951)
$CaCO_3$ (%) (Scheibler)	2.03	6.91	Ülgen ve Yurtsever,1974*
pH	7.62	7.85	Richards, 1954
EC (mmhos/cm)	0.03	0.03	Richards, 1954;
Organic matter (%)	1.45	1.74	Walkey (1934)
Olsen-P(kg/da) Available. P	0.40	1.09	Olsen ve Sommers (1982)
Exc.Ca (ppm)	24145.3	23538.7	FAO, 1990
Exc.Mg (ppm)	1807.1	2210.2	FAO, 1990
Exc.Na			
Exc.K			
Available.Fe (ppm)	8.43	8.74	Follet, 1969
Cu (ppm)	13.64	11.58	Follet, 1969
Zn (ppm)	2.05	2.07	Follet, 1969
Mn (ppm)	78.74	41.02	Follet, 1969

Plant Materials

"Crimson Sweet" watermelon (*Citrullus lanatus*) variety was used as plant material. The variety is medium late standard variety and highly adapted to different soil and climate conditions. Round-oval fruit shape and bright red fruit flesh.

Properties of Plant Growth Regulators, Farm manure and Vermicompost

Endoroots soluble under the trade name as plant growth regulators: cocktail mycorrhizae (*Glomus intraradices* (25%), *G. mosseae* (24%), *G. aggregatum* (1%), *G. monosporum* (1%), *G. deseticola* (1%), *G. brasilianum* (1%), *G. etunicatum* (1%), *G. margarita*

(1%), Crop-Set: *Lactobacillus acidiophilus* fermentation product leaf fertilizer, ISR-2000 (855,81 gl^{-1} *Lactobacillus acidophilus* active ingredients) were used.

The matured farm manure used in this study was collected from commercial farms and contained 59% organic matter, 1.6% N and pH was 8.2. Vermicompost used in the study was produced from cow manure and contained 64.18% organic matter, 2.58% N and pH was 7.4. Both of farm manure and vermicompost were used as organic fertilizers. Some physical and chemical analyzes of used and analyzed vermicompost and farm manure content results were similar with this study results (Çıtak et al., 2011; Göksu and Kuzucu, 2017). The EC value of vermicompost is $3.4dSm^{-1}$.

Production seedlings of watermelon were transplanted with three replicates and six different applications to the main plots on 2nd May 2018. Experimental area was 20 m in length and 12.5 m in width. Ten plants were transplanted to plots (9 m^2) by 2 x 0.5 m intervals. Applications were distributed randomly and irrigated by a drip system.

Fertilizer applications; for control, no applications of any fertilizer and plant growth regulators, 150 kg da^{-1} vermicompost (% 2.58 N), 2 tons da^{-1} farm manure (% 1.6 N), 250 g da^{-1} Endoroots, 60 ccda^{-1} ISR-2000 and 90 cc da^{-1} Crop-Set were applied. Endoroots, ISR-2000 and Crop-Set doses were firm recommendations. Vermicompost and farm manure doses were determined according to the region soil structures and farmer practices. In the experiment "Neemazal" was used three times for plant protection.

The Parameters Studied as Part of the Study

Three fruits were chosen randomly from each plot for pomological analyzes. Fruit weight (kg) was assessed by digital precision scales, and fruit width, length, and thickness were measured via ruler and fruit shell thickness (mm) was measured via digital calipers. Additionally, Total Soluble Solids (%) was detected in fruit juice samples of the collected fruits by digital refractometer.

Fruit samples were also subjected to biochemical assessments including lycopene (µg/g), anthocyanin (mg/g FW) and (mg/kg FW) content. In order to determine the lycopene content, 6 g of fruit was weighed in 40 ml amber test tubes. Pure acetone containing 5 ml of 0.05 % Butyl Hydroxy Toluene (BHT) was vortexed for 1 min with 5 ml of 95% ethanol and 10 ml of hexane. The samples were taken and shaken into the ice bath for 20 minutes, and 3 ml of deionized water was added to verify lycopene content. Hexan layer of the mixture was read at 503 nm in spectrophotometer (Fish et al 2002; Kong and Ismail 2011).

Total anthocyanin was identified according to the method mentioned by Giusti and Wrolstad (2001). The extract was prepared by homogenizing 5 g of fruit samples in 10 ml of 1% HCl containing methanol solution. The absorbances of the samples were read at 530 and 700 nm in the spectrophotometer.

Total phenolic amount was determined according to Folin-Ciocalteu method. The plant tissue homogenized in ethanol was centrifuged overnight after incubation at -80˚C. 1 ml ethanol, 5 ml distilled water, 1 ml folin and 3 ml 2% Na_2CO_3 were added to the supernatant and incubated for 2 hours in the dark at room temperature and then read at 760 nm on the spectrophotometer (Slinkard and Singleton, 1977; Chandler and Dodds, 1983).

Total chlorophyll (mg/g FW) content, 1 g of leaf tissue was homogenized in acetone and absorbances of samples were read at 662,645 and 470 nm in spectrophotometer (De Kok and Graham, 1980; Lichtenthaler and Welburn, 1983).

Statistical Analysis

The study was carried out in randomized block experiment design with three replications under open field conditions. Obtained data were analyzed by using variance analysis using MINITAB package program and important parameters were subjected to Duncan multiple comparison at $P<0.05$ significance level (Yurtsever, 1984).

RESULTS and DISCUSSION

As a result of the study, fruit weight was identified between 2.93 kg and 5.01 kg (Table 2). Fruit weight results of plant growth regulator applications were higher than the control (Crop-Set by 5.8 %, ISR-2000 by 132.5% and Endoroots by 18.6%) application. When compared with control, yield was significantly increased by plant growth regulators, farm manure and vermicompost. In this study, Endoroots (250 g da^{-1}) is the most appropriate application in Adıyaman as the highest yield was recorded from Endoroots. It is thought that the Endoroots application would give good results because of regular transport of plant nutrients especially P and water to the plant. Similarly, Kiracı and Karataş (2005) examined the effects of plant growth regulators on tomato yield, and reported that Crop-Set and ISR-2000 were played an important role in increasing fruit weight. Arikan et. al., (2013) were also reported plant growth regulators increasing fruit and vegetable yield Plant growth regulators and microbial fertilizers were compared with green manure and presented successful results on tomato cultivation in the study conducted by Göktekin and Ünlü, 2016). Vermicompost application similarly to study has positive effect on yield of greenhouse peppers, fennel and tomato (Arancon et. al., (2004); Darzi et. al., (2008); Zaller, 2007).

As part of the study, the effects of vermicompost and farm manure compost at different volume ratios on rhizosphere environment, quality and yield of cucumber were studied. The results showed that vermicompost and cow manure compost could significantly improve the soil physical and chemical properties, increase soil nutrients, organic matter and enzyme activities; the cucumber yield and the contents of free amino acid, soluble protein, soluble sugar and vitamin C in fruit were also enhanced (Joshi et. al., 2015). By the fact that plant growth regulators play a big role in increasing the yield and fruit weights of watermelon.

When control and plant growth regulator applications were compared for fruit height, width and fruit shell thickness the results of all applications were not found statistically significant. Fruit width and height results were higher than the control application. The highest result of fruit width and height were obtained from vermicompost application by 20.66 cm and 22.39 cm respectively (Table 2).

The content of TSS was found higher on plant growth regulators applied plots compared with control plots. Highest % TSS was identified under Endoroots application (Table 2). The results were found 0.01 % statistically significant. According to Koca, 2006; TSS content of carrot ranged between 6.87-11.01%. Researcher has achieved higher TSS results. Gündüz and Özdemir (2012) reported that there is a positive relationship between the number of fruits and TSS. The application of plant growth regulators on watermelon plants increased the amount of lycopene at rates ranging from 0.2 % to 1 %. The highest amount of anthocyanin and phenolic substance were obtained from Endoroots application with 0.5 % and 8.5 %, respectively (Table 2). Similarly, Kiracı et. al., 2013 have reported that plant growth regulators have positive effects on anthocyanin, phenolic substance and lycopene content of carrot. Where plant growth regulator and two different organic fertilizers were applied on watermelon, TSS, lycopene and total chlorophyll were determined statistically significant.

Total chlorophyll content has been increased when all Plant growth regulator applications were compared with control. Highest result was obtained from Endoroots application by 9.23 (Table 2). Different azotobacteria species are effective on antioxidant enzymes, caratenoid, chlorophyll pigments, soluble protein and dry matter (Karaboz and Özcan, 2005).

In this study, yield was increased by plant growth regulator and farm manure applications. Crop-Set as a plant growth regulator has positive effect on yield in around the world by the studies with different plant. For example of these studies, Crop-Set application was increased marketable yield of potato in a ranked of 5.83 % (Anonymous, 1997a); Crop-Set has been applied to Dark Red Norland variety of potato; marketable yield was increased in a ranked of 20.9% (Anonymous, 1997b).

According to the control application, the highest efficiency was obtained with 11.63 tons da^{-1} in Endoroots application and Endooroots application was determined statistically important (Table 2). Zhang et al. (2011) examined the effects of vermicompost on watermelon yield and quality in different volume ratios, they stated that additional vermicompost could significantly increase the content of the present N, present P, present K, organic matter in the soil and the content of N, P, K in watermelon plants and fruits. Çetinkaya and Dura (2010) were reported; Endoroots application had good effect on corn yield and corn quality.

Farm manure and vermicompost applications were measured higher in all the parameters examined in the watermelon compared to the control application (Table 2). As vermicompost application compared to animal manure, vermicompost application had higher and positive effects on fruit weight, fruit width, fruit height, fruit thickness and yield. Vermicompost application could give good results than farm manure. This could be because of physical and chemical properties of vermicompost were better than those of animal manure. Compared to cow dung compost, the vermicompost was better at the same volume ratio, and adding 25% worm casing showed the best effect (JiRui et al., 2013). The amount of lycopene, anthocyanin, total chlorophyll and phenolic substance were higher in vermicompost application than farm manure. TSS rate was low in vermicompost application to farm manure due to dilution effect or Karadoğan et al., 1997 stated that farm manure can be interpreted as increasing the efficiency of nitrogen and decreasing the dry matter rate.

CONCLUSION

Results indicated that both plant growth regulators, farm manure and vermicompost fertilizers can be used successfully in watermelon cultivation under semi-arid ecological conditions. When the effects of plant growth regulators, farm manure and vermicompost fertilizers applications on fruit yield and some quality parameters were evaluated; it was concluded that plant growth regulators, farm manure and vermicompost fertilizers applications could supply significant benefits in watermelon cultivation. Based on the results, Endoroots and vermicompost applications were found to be beneficial and can be recommended for watermelon cultivation. The doses of 250 g da-1 and 150 kg da-1 were the most efficient for Endoroots and vermicompost, respectively.

Table 2. Some Phenological and Pomological Properties of Watermelon Cultivars.
Çizelge 2. Karpuz Çeşitlerinin Bazı Fenolojik ve Pomolojik Özellikleri

Variables *Değişkenler*	Endoroots *Endoroots*	ISR-2000 *ISR-2000*	Crop-Set *Crop-Set*	Farm Manure Çiftlik Gübresi	Vermicompost *Vermikompost*	Control *Kontrol*
Fruit Weight (kg)	3.6	3.39	3.11	4.80	5.01	2.93
Fruit Width (cm)	19.4	18.64	17.38	20.53	20.66	19.90
Fruit Height (cm)	19.9	20.10	21.67	21.62	22.39	18.03
Fruit Shell Thickness (mm)	12.5	12.25	12.16	11.70	12.86	13.40
TSS (%)	15.9a***	12.69c	13.44bc	15.02ab	13.29bc	10.47d
Lycopene (µg/g)	58.5	57.96	57.99	58.04	58.04	57.86
Total Anthocyanin (mg/g FW)	0.71	0.70	0.66	0.69	0.70	0.66
Total Phenolic (mg/kg FW)	129	121	113	126	129	118
Total Chlorophyll (mg/g FW)	9.23	9.07	8.88	9.10	9.16	7.71
Yield (ton/da)	11.63**	8.56	6.53	7.45	9.27	5.79

The parameters that are not lettered against the applications are not statistically different from each other. Statistically different applications are shown in the line by showing ** ($p \leq 0.1$) and *** ($p \leq 0.01$).
Uygulamalar karşısında harflendirilmemiş parametreler istatistiksel olarak birbirinden farklı değildir. Farklı olan uygulamalar ** ($p \leq 0.1$) ve ***($p \leq 0.01$) ile gösterilerek harflendirmeler satırda yapılmıştır.
a, b, c; Sütün içerisinde aynı harf ile işaretlenmiş ortalamalar P seviyesinde istatistiksel olarak birbirinden farklı değildir. Means followed by the same letter within the column are not statistically different a

Statement of Conflict of Interest

Authors have declared no conflict of interest.

Author's Contributions

The contribution of the authors is equal.

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