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Araştırma Makalesi (Research Article)

Determination of the Optimum Mulch-Irrigation Program Combination for Young Apple Trees

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Abstract: The gradual increase demand for water resources, the interest for growing techniques provides irrigation water saving in agricultural production and have no undesired impacts on yield, crop quality, growth and development. This study determined the effects of different mulch materials (black textile, rose oil processing wastes, wheat straw, and no mulch) and irrigation programs on growth of in an orchard for Fuji apple variety grafted on MM106 rootstock on irrigation water, water consumption, shoot number, shoot diameter, shoot length, leaf area index and trunk cross-sectional area. The highest vegetative development was obtained at mulch treatments and frequently irrigated 1st irrigation program. 1st irrigation program was determined as recommended irrigation when the available water resources are sufficient and also 2nd irrigation program together with mulch materials when available water resources are scarce. Each mulch treatment saved water compared to control as 22.0-31.3%, 21.2-28.7% and 17.8-23.5% in 2009, 2010 and 2011, respectively. Black textile was determined the most suitable mulch material for young apple trees according to results of water saving and vegetative development. Rose oil processing wastes and straw also can be used as mulch materials.

Genç Elma Ağaçları için Uygun Malç-Sulama Programı Kombinasyonunun Belirlenmesi

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Anahtar kelimeler

Elma,
Siyah taban örtüsü,
MM106,
Vejetatif gelişme,
Su tasarrufu.

Öz: Su kaynakları için talep giderek artmaktadır ve tarımsal üretimde sulama suyu tasarrufu sağlayan ve verim, ürün kalitesi, büyüme ve gelişme üzerinde olumsuz etkileri olmayan yetiştirme tekniklerine olan ilgi de artmaktadır. Bu çalışma, MM106 anaçlı Fuji elma çeşidinde farklı malç uygulamaları (siyah taban örtüsü, gül posası işleme atığı, buğday samanı ve malçsız konu-kontrol) ve sulama programlarının sulama suyu, evapotranspirasyon, sürgün çapı, sürgün sayısı, sürgün uzunluğu, yaprak alan indeksi ve gövde kesit alanı üzerinde etkilerinin belirlenmesi amacıyla yapılmıştır. Her bir malç uygulaması için üç farklı sulama programı (sulamaya etkili kök derinliği bölgesindeki elverişli suyun %20, 40 ve 60'ı tüketildiğinde başlama) en uygun sulama programını belirlemek için denenmiştir. En yüksek vejetatif gelişim malç uygulamalarında ve sık sulama yapılan 1. sulama programlarında elde edilmiştir. Tavsiye edilen sulama programı su kaynaklarının elverişli ve yeterli olduğu bölgelerde 1. sulama programıdır. Elverişli su kaynakları miktarının yetersiz olduğu zamanlarda ise malç uygulamalarıyla birlikte 2. sulama programı da uygulanabilir. Malç uygulamalarından elde edilen su tasarrufu miktarı control konusuna göre 2009,

2010 ve 2011 yıllarında sırasıyla 22.0-31.3%, 21.2-28.7% and 17.8-23.5% arasında değişmiştir. Su tasarrufu ve vejetatif gelişim sonuçlarına göre genç elma ağaçları için siyah taban örtüsü en uygun malç materyali olarak belirlenmiştir. Gül posası işleme atıkları ve buğday samanı da malç materyali olarak kullanılabilir.

1. Introduction

As the using of water in other fields (industrial production, domestic use, etc.) has been increasing over the time, the available water amounts for agricultural production have been decreasing (Önder et. al., 2005). So to increase water-use efficiency is mandatory (Naor et. al., 2008). That's why, available water resources must be used more carefully. The importance of studies for more efficient use of available water resources is increasing. The studies on the applications which ensure water saving and do not have the negative effects on vegetative development, yield and crop quality are going on all over the world. Mulch using is one of these applications. It provides water saving and has positive effect on plant growth development besides preventing weed growth in apple orchards (Neilsen, et al., 2003; Hogue et. al., 2005).

Amount of irrigation water and irrigation time of plants must be determined accurately to get full efficiency from irrigation (Barragan and Wu, 2001). Haphazard irrigations obstruct plants from obtaining irrigation efficiency which results in un- desired consequences such as salinity-sodium, high cost and low yields. Apple production quantity of Turkey is estimated as 4.0 % of the world's total apple production and apples are one of the most important fruits produced (FAO, 2019). Isparta is at first rank on apple production nearly 20.4% of the country's total (3.618.752 tons) (TUİK, 2019). There are some problems on apple growing (irrigation scheduling, weed control etc.) (Küçükumruk and Ay, 2010).

This study was aimed to determine the effects of different mulch materials namely black textile, straw (wheat straw) and rose oil processing wastes on water saving, evapotranspiration and vegetative development of Fuji apple variety (grafted onto MM106 rootstock. Also, three different irrigation programs have been used for each different mulch materials and the most suitable irrigation program was determined for Fuji variety grafted on MM106 rootstock.

2. Materials and Methods

2.1. Study area and plant material

This experiment was conducted for the three consecutive years (2009- 2011) at Fruit Research Institute (37°49'17.97"N and 30°52'22.44"E), Eğirdir-Isparta, Turkey. The experimental area has a transition climate between Mediterranean and Central Anatolia. The soil of experimental area was loamy, contained low salt content, pH 8.15 and low soil organic matter content. Table 1 shows the physical properties of the experimental soil. According to US Salinity Laboratory Graphical System, the salinity level of the irrigation water, which are in 250- 750 ECx10⁶ is included in category C₂, and S₁ in terms of SAR value (USSS, 1954). Irrigation water was classified as C₂S₁ suitable for irrigation of the experimental plots. Apple trees were planted in March 2009 at 4 m x 3 m of distance and Fuji variety (grafted onto MM106 rootstock) was used in this experiment.

Table 1. Soil characteristics of the experimental area

Depth (cm)	FC (%)	WP (%)	γ (g cm ⁻³)	FC (mm)	WP (mm)	AWHC (mm)
0-30	23.80	10.90	1.52	108.53	49.70	58.83
30-60	21.32	10.25	1.48	94.66	45.51	49.15
60-90	22.60	10.55	1.53	103.73	48.42	55.31
90-120	23.50	10.70	1.57	110.69	50.40	60.29
0-90 cm (effective root zone)						163.29

FC: field capacity, WP: wilting point, γ : unit weight of soil, AWHC: available water holding capacity

2.2. Study treatments

The study was conducted considering consisted of four mulch treatments (including control) and three different irrigation programs for each mulch treatments. Mulch treatments: no mulch, Control (C); black textile-polypropylene woven cloth (100 g m⁻²) (B); straw-wheat straw (S) and rose oil processing wastes (R)- the rose waste obtained from the wastes of the rose oil processing factories in Isparta province of Turkey were used after sun-dried. Each mulch treatment had three different irrigation programs (1st, 2nd and 3rd irrigation programs) 1st, 2nd and 3rd irrigation programs treatments include irrigation of the field with water holding capacity of 20, 40 and 60% was used at 0-90 cm depth of the soil.

In the study, drip irrigation system was used. Two lateral pipes were used for each tree row. The emitters (having 4 l h⁻¹ flow rate) spacing were 0.75 m on each lateral sides. Digital tensiometers (Soilspec digital tensiometer, JGK TECH, Australia) were used for measuring soil water (placed at 30, 60, 90 and 120 cm depth). Before first irrigation, calibration of tensiometers was made to determine the soil water which corresponds. Programmed irrigation applications were initiated after the available moisture at 0-90 cm soil depth was reached to field capacity at the end of the full bloom period each year.

(ET) was determined according to soil water balance method (Eq. (1)) (James, 1988) for each irrigation treatment.

$$ET = I + R + C_r - D_p - R_f \pm \Delta s \quad (1)$$

In Equation (1); ET, evapotranspiration (mm); I, irrigation water amounts (mm); C_r, capillary rise (mm); R, rainfall (mm); R_f, surface run-off (mm); D_p, water leakage by deep percolation (mm); Δs, change in profile soil water content (mm). C_r and R_f were considered as zero, since there were not any ground water problems in the area and emitter discharge rate was selected in accordance with infiltration rate. Deep percolation was calculated after each precipitation during irrigation season. Precipitation was measured with a pluviometer after every rainy day. For determining the irrigation water amounts, The Equation (2) was used (Kanber, 2002).

$$I = \frac{(P_{WFC} - P_w) \times D \times \gamma \times P}{100} \quad (2)$$

In the Equation 2, I; the amount of applied irrigation water (mm), P_{WFC}; field capacity (%), P_w; water level at effective rootzone before irrigation (%), D; wetting depth (mm), γ; unit weight of soil (g cm⁻³) and P; wetting percentage (%). We determined P as 38.0% (0.38) end of the calculating according to Yıldırım (2005).

The plots were irrigated until they reached field capacity for each irrigation. After the nurseries were planted in March 2009, weeds in the study area were hoed on 15 May, and drip irrigation system was laid. After placing tensiometers, mulch materials were laid on both sides of the trees with 0.70 m width, and in total 1.40 m width. The thickness of straw and rose oil processing wastes was 0.20 m.

2.3. Measurement of vegetative growth

Beginning from the planting year, shoot numbers, shoot diameter (mm) and shoot length (cm) of single-year shoots for all trees were measured in during dormancy period in February. Digital calipper was used for measuring shoot diameter.

2.4. Leaf area index (m²/m²)

Totally 250 leaves were picked from the one year old shoots of all trees for each plot to determine leaf area index at the end of September during study. The digital planimeter (Koizumi KP-90 N) was used to measure leaf area. We calculated “leaf area index” by using Equation 3 (Ünlü, 2000).

$$\text{Total leaf area (for each tree)} = \text{Leaf area (m}^2\text{)} \times \text{total leaf numbers (for each tree)}$$

$$\text{Leaf area index (m}^2\text{/m}^2\text{)} = \frac{\text{Total leaf area (m}^2\text{) (for each tree)}}{\text{Unit area for each tree (m}^2\text{) (4 m x 3 m)}} \quad (3)$$

2.5. Trunk cross-section area (cm²)

In the first year, after the planting and in the following years, every year during dormancy period, the trunk diameters of all trees were measured on two different directions (east-west and north-south) at 15 cm above the graft point of all trees, and trunk cross-sectional areas were calculated by means of the Equation (4).

$$TCSA = \pi \times r^2 \quad (4)$$

In the equation;

TCSA = trunk cross-section area (cm²)

r = trunk radius (cm)

2.6. Experimental design and statistical analysis

The experiment was designed according to split plot design. Main plots were mulch treatments and sub plots were irrigation programs. There were three replications for each treatments and each replication had twenty one apple trees (Figure 1). Only five trees (grey color in Figure 1) were used for measurements. The analysis of variance (ANOVA) test for the data was conducted with JUMP software program and differences among treatments were compared by means of LSD test.

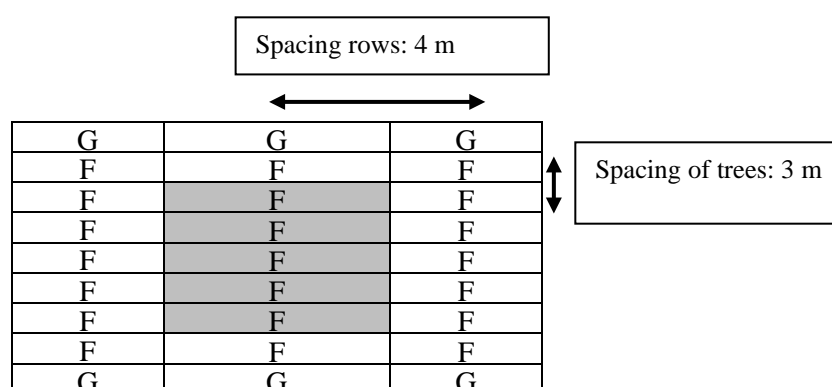


Figure 1. An experimental plot of the study.
 (F: Fuji variety, G: Granny Smith-pollinator variety)

3. Results

3.1. Irrigation water (I) and evapotranspiration (ET)

Irrigation water (I) and evapotranspiration (ET) were presented in Table 2, Table 3 and Table 4. The first irrigation dates were 20 May in 2009, 18 May in 2010, and 23 May in 2011, while the latest irrigation dates were 27 September in 2009, 27 September in 2010 and 22 September in 2011, respectively. Irrigation water amounts obtained from treatments were in the range of 279.2-424.1 mm in 2009, 306.7-461.5 mm in 2010 and 363.1-504.7 mm in 2011. It was determined that the plant water consumption varied in the range of 289.2-516.1 mm in 2009, 317.8-565.4 mm in 2010 and 372.2-570.3 mm in 2011. Mulch treatments required less irrigation water according to control treatment beginning from the first year.

Table 2. Irrigation water amounts (I), evapotranspiration (ET), evaporation (Epan) and precipitation (P) in 2009

Months	Epan	P	Control				Rose oil processing wastes				Straw		Black textile	
May ¹	77.4	10.9	40.4	57.8	18.9	41.0	18.9	18.9	40.9	18.9	18.9	40.9	18.9	18.9
June	236.1	15.1	90.1	83.2	61.0	73.2	81.6	65.0	65.4	86.6	61.0	72.8	83.3	61.2
July	254.3	8.8	113.3	85.9	124.6	89.5	81.9	67.5	70.5	45.3	60.0	68.9	41.7	63.5
Aug.	238.3	0.7	109.7	88.1	127.2	86.6	86.5	135.5	92.1	84.0	62.3	66.3	82.5	62.0
Sept. ²	114.1	35.4	70.6	95.5	71.5	40.3	55.9	22.5	37.5	62.3	83.6	42.1	52.8	79.2
Total	920.2	70.9												
Total I			424.1	410.5	403.2	330.6	324.8	309.4	306.4	297.1	285.8	291.0	279.2	284.8
Total ET			516.1	498.0	492.1	342.2	332.6	318.8	317.7	307.1	293.8	302.5	289.2	291.9

¹Total values were between May 20th and 31st.

²Total values were between September 1st and 27th.

Table 3. Irrigation water amounts (I), evapotranspiration (ET), evaporation (Epan) and precipitation (P) in 2010

Months	Epan	P	Control				Rose oil processing wastes				Straw		Black textile	
May ¹	66.1	26.0	57.7	35.6	39.0	48.0	28.9	31.0	46.9	22.6	26.7	44.4	18.8	20.2
June	164.9	50.3	67.5	83.2	63.6	68.3	85.2	61.1	63.8	83.8	61.2	64.8	83.5	61.3
July	233.8	2.5	140.9	122.4	129.9	92.9	92.1	62.6	96.9	87.5	62.0	90.9	84.1	60.8
Aug.	253.6	1.7	117.1	85.6	125.4	93.9	88.2	122.7	70.1	85.5	123.5	72.8	44.7	62.1
Sept. ²	126.6	8.1	78.3	103.5	74.6	60.6	61.3	67.6	66.3	58.7	61.4	55.7	84.4	102.3
Total	870.7	88.6												
Total I			461.5	430.3	432.5	363.7	355.7	345.0	344.0	338.1	334.8	328.6	315.5	306.7
Total ET			565.4	536.3	533.9	377.2	366.7	358.2	357.7	348.7	344.6	343.3	327.5	317.8

¹Total values were between May 18th and 31st.

²Total values were between September 1st and 27th.

Table 4. Irrigation water amounts (I), evapotranspiration (ET), evaporation (Epan) and precipitation (P) in 2011

Months	Epan	P	Control				Rose oil processing wastes				Straw		Black textile	
May ¹	40.7	15.0	29.0	30.6	31.0	21.0	22.4	23.4	22.0	24.0	23.5	26.8	23.1	21.5
June	188.0	20.6	104.0	127.7	121.2	90.6	87.6	61.5	88.0	86.3	61.2	85.2	88.0	63.5
July	242.9	0.0	140.1	84.8	121.4	113.7	87.9	125.2	111.3	91.5	129.4	89.6	88.6	66.7
August	237.9	8.3	140.9	127.0	61.2	96.4	92.2	64.3	92.3	91.3	64.5	122.1	89.4	129.1
September ²	156.2	4.5	90.7	113.6	134.7	93.2	100.6	121.1	81.8	95.8	89.8	62.2	90.4	82.3
Total	844.2	48.4												
Total I			504.7	483.7	469.5	414.9	390.7	395.5	395.4	388.9	368.4	385.9	379.5	363.1
Total ET			570.3	543.8	533.8	426.4	403.9	405.7	412.3	400.1	376.4	402.8	391.6	372.2

¹Total values were between May 23th and 31st.

²Total values were between September 1st and 22nd.

3.2. Vegetative growth

Shoot number

Shoot numbers obtained during the study is shown on Table 5. It was determined that mulch and irrigation program treatments had statistically important effects in 2009 ($p < 0.01$). The highest vegetative development was obtained from black textile and rose oil processing wastes mulch treatments and from 1st irrigation program among irrigation programs. Mulch x irrigation program interaction was found significant in 2010 ($p < 0.01$). The highest shoot numbers were determined in 1st and 2nd irrigation programs of the mulch treatments. According to the results in 2011, the mulch and irrigation programs had separate effects on shoot numbers ($p < 0.01$). Black textile and the 1st irrigation program had the highest values among treatments. In general, mulch treatments had a positive effect on shoot numbers and it was observed that 1st irrigation program also had a similar effect.

Table 5. Shoot numbers of apple trees in 2009, 2010 and 2011

Mulches	Irrigation programs			Average
	1 st program	2 nd program	3 rd program	
2009				
Black textile	5.13 <i>ns</i>	4.27	4.17	4.52 a**
Straw	4.40	4.27	3.47	4.04 ab
Rose oil processing wastes	4.40	4.33	3.79	4.18 a
Control	4.27	3.47	3.29	3.67 b
Average	4.55 a**	4.08 b	3.68 b	
2010				
Black textile	14.40 a**	13.07 ab	9.47 def	12.31
Straw	13.03 ab	10.80 cd	8.73 efg	10.85
Rose oil processing wastes	12.27 bc	11.33 c	10.87 cd	11.49
Control	9.73 de	8.03 g	7.73 fg	8.49
Average	12.36	10.73	9.28	
2011				
Black textile	51.67 <i>ns</i>	30.67	24.33	35.56 a**
Straw	36.00	26.33	24.00	28.78 b
Rose oil processing wastes	32.00	26.67	22.67	27.11 b
Control	29.67	23.33	19.67	24.22 b
Average	37.33 a**	26.75 b	22.67 b	

**Means followed by the same letter are not significantly different (LSD test, P<0.01; ns: no significant).

Shoot length

According to the results of shoot length (Table 6), the mulch x irrigation program interaction in 2009 and 2010 was effective as statistically 1% level (p<0.01). 1st and 2nd irrigation programs in mulch treatments had the highest values. Mulch and irrigation program had separate effects (p<0.01) in 2011. The highest shoot lengths were obtained from black textile among mulch treatments and from 1st irrigation program among the irrigation programs.

Table 6. Shoot length (cm) values of apple trees in 2009, 2010 and 2011

Mulches	Irrigation programs			Average
	1 st program	2 nd program	3 rd program	
2009				
Black textile	65.81 a**	56.34 b	39.80 c	53.98
Straw	52.24 b	41.51 c	24.25 e	39.33
Rose oil processing wastes	54.51 b	40.71 c	40.16 c	45.12
Control	37.50 cd	35.32 cd	32.99 d	35.27
Average	52.51	43.47	34.30	
2010				
Black textile	105.19 a**	91.58 b	62.79 g	86.52
Straw	94.21 b	81.42 cd	59.64 gh	78.42
Rose oil processing wastes	82.98 c	75.72 ef	57.57 gh	72.09
Control	76.47 de	69.73 f	56.04 h	67.41
Average	89.72	79.61	59.10	
2011				
Black textile	68.47 <i>ns</i>	66.03	61.70	65.40 a**
Straw	64.33	62.07	54.97	60.46 bc
Rose oil processing wastes	63.90	61.27	58.63	61.27 b
Control	63.27	58.67	50.83	57.59 c
Average	64.99 a**	62.00 b	56.53 c	

**Means followed by the same letter are not significantly different (LSD test, P<0.01; ns: no significant).

Shoot diameter

According to the results of shoot diameter (Table 7), mulch x irrigation program interaction in 2010 was found significant while mulches and irrigation programs had separate effects in the other

years. The highest shoot diameter values in 2009 were obtained from rose oil processing wastes and black textile in mulch treatments and from 1st irrigation program. 1st and 2nd irrigation programs of mulch treatments had the highest shoot diameter according to the results of 2010. In the last year, black textile was at the first rank among mulch treatments, and 1st and 2nd irrigation programs were in the same group statistically.

Table 7. Shoot diameter (mm) of apple trees in 2009, 2010 and 2011

Mulches	Irrigation programs			Average
	1 st program	2 nd program	3 rd program	
2009				
Black textile	5.31 <i>ns</i>	4.90	4.77	4.99 ab*
Straw	4.79	4.70	4.24	4.58 b
Rose oil processing wastes	6.46	5.22	4.37	5.35 a
Control	4.57	4.38	4.20	4.39 b
Average	5.28 a*	4.80 ab	4.39 b	
2010				
Black textile	9.80 a**	9.01 b	7.24 de	8.68
Straw	9.11 b	9.10 b	7.07 de	8.43
Rose oil processing wastes	9.04 b	7.73 c	6.95 e	7.91
Control	7.54 cd	7.16 de	6.78 e	7.16
Average	8.87	8.25	7.01	
2011				
Black textile	8.14 <i>ns</i>	7.82	7.42	7.79 a*
Straw	7.87	7.84	7.00	7.57 ab
Rose oil processing wastes	7.70	7.49	7.41	7.53 ab
Control	7.52	7.28	6.87	7.22 b
Average	7.81 a**	7.61 a	7.18 b	

*Means followed by the same letter are not significantly different (LSD test, P<0.05).

**Means followed by the same letter are not significantly different (LSD test, P<0.01; ns: no significant).

Leaf area index (LAI)

While mulch x irrigation program interaction had significant effect on LAI (p<0.01) in 2010, mulch and irrigation program had significant effects on LAI (p<0.01) separately in 2011. LAI values ranged between 0.123 m² m⁻² and 0.238 m² m⁻² in 2010. Black textile x 1st irrigation program interaction had the highest LAI and the lowest LAI was obtained from control x 3rd irrigation program interaction. LAI was ranged 0.136 m² m⁻² and 0.333 m² m⁻² and black textile mulch had the highest average LAI (0.258 m² m⁻²) in 2011. Straw and rose oil processing wastes had similar results. LAI values of study in 2011 were higher than LAI values in 2010. According to irrigation programs, while irrigation water amounts increased, LAI increased.

Table 8. Leaf area index (m² m⁻²) of the study in 2010 and 2011

Mulches	Irrigation programs			Average
	1 st program	2 nd program	3 rd program	
2010				
Black textile	0.238 a**	0.214 b	0.150 fg	0.195
Straw	0.203 bc	0.163 ef	0.140 g	0.171
Rose oil processing wastes	0.214 b	0.188 d	0.146 g	0.180
Control	0.190 cd	0.166 ef	0.123 h	0.170
Average	0.22	0.18	0.14	
2011				
Black textile	0.333 <i>ns</i>	0.272	0.168	0.258 a**
Straw	0.304	0.252	0.162	0.239 b
Rose oil processing wastes	0.303	0.252	0.168	0.241 b
Control	0.264	0.209	0.136	0.203 c
Average	0.301 a**	0.246 b	0.159 c	

**Means followed by the same letter are not significantly different (LSD test, P<0.01; ns: no significant)

Trunk cross-sectional area (TCSA)

At measurements after planting in 2009, there was no differences among all treatments as statistically (Table 9). According to the measurements results of 2009 following the first measurement, mulch treatments and irrigation programs have separate effects ($p < 0.01$). The highest values were obtained from black textile among mulch treatments and from the 1st irrigation program among the irrigation programs. The effects of mulch x irrigation program interaction were significant in 2010 and 2011 ($p < 0.05$). A significant increasing was determined of measurements TCSA for all treatments during the study.

Table 9. Trunk cross-sectional area values (cm²) of apple trees in the study

Mulches	Irrigation programs			Average
	1 st program	2 nd program	3 rd program	
2009 (at planting)				
Black textile	110.72 <i>ns</i>	111.89	114.31	112.31 <i>ns</i>
Straw	120.16	113.94	109.40	114.50
Rose oil processing wastes	105.05	113.75	110.56	109.79
Control	105.69	101.47	113.75	106.97
Average	110.41 <i>ns</i>	110.27	112.01	
2009				
Black textile	250.61 <i>ns</i>	207.21	205.95	221.25 a**
Straw	224.25	190.54	177.26	197.35 b
Rose oil processing wastes	187.86	183.22	188.42	186.50 b
Control	186.19	159.79	156.84	167.61 c
Average	212.23 a**	185.19 b	182.11 b	
2010				
Black textile	756.83 a*	585.42 bc	431.27 efg	591.18
Straw	598.98 b	507.27 cde	419.02 fg	508.42
Rose oil processing wastes	570.28 bc	474.72 def	408.16 fg	484.39
Control	523.10 bcd	424.40 fg	376.75 g	441.42
Average	612.30	497.95	408.80	
2011				
Black textile	1919.15 a*	1284.86 bc	977.99 cd	1393.99
Straw	1361.03 b	1191.14 bc	947.65 cd	1166.61
Rose oil processing wastes	1033.33 bcd	968.67 cd	956.26 cd	986.09
Control	1016.27 bcd	961.09 cd	759.37 d	912.24
Average	1332.45	1101.44	910.32	

*Means followed by the same letter are not significantly different (LSD test, $P < 0.05$).

**Means followed by the same letter are not significantly different (LSD test, $P < 0.01$; ns: no significant)

4. Discussion and Conclusion

4.1. Irrigation water (I) and evapotranspiration (ET)

As the mulch materials prevented the sunlight, the evaporation from the soil surface was minimized; therefore, evapotranspiration decreased and also irrigation water amounts. Rose oil processing wastes mulch was less effective than wheat straw mulch, while black textile mulch was the most effective. For example, in 2009, applied irrigation water amounts was 424.1 mm to the control treatment for the 1st irrigation program while it was 330.6 mm, 306.4 mm and 291.0 mm in rose oil processing wastes, straw and black textile mulch treatments, respectively. Irrigation water amounts obtained from mulch treatments were in the range of 306.7-363.7 mm and 363.1-414.9 mm for second and third years old apple trees. Uçar et al. (2009) obtained for Galaxy Gala apple variety grafted onto M9 rootstock without mulches as between 355.7-446.5 mm and 359.2-538.9 mm for two and three years old apple trees in the same area. When comparing the results, it can be said that mulch treatments had water saving.

Mulch treatments had significant effects on irrigation intervals. While more frequent irrigation was made in control treatment, irrigation interval was longer for mulch treatments. Irrigation numbers and amounts were the highest for the 1st irrigation treatments. For example, while irrigation interval for 1st irrigation programs were 4 days for control treatments, they were 5-6 days for the other treatments.

Some of researchers stated that more soil water could be stored at root zone with mulching and irrigation interval was longer than no mulch treatments and less amounts of irrigation water was used (Treder et al., 2004; Hogue et al., 2005; Zambreno et al.; 2005; Li et al., 2013).

Irrigation water and plant water consumption increased for all treatments continuously during the study. Reason for the increasing is that young apple trees growth continuously from year to year. Similarly, the differences among irrigation water amounts of control and mulch treatments was higher in 2009 while it narrowed down in 2010 and 2011. The reason is, apple trees in mulch treatments had higher vegetative growth compared to trees in control treatments, therefore they consumed more irrigation water. Water saving in mulch treatments was %22.0-31.3, %21.2-28.7 and %17.8-23.5 in 2009, 2010 and 2011, respectively, when it was compared to control treatment. Phadung et al. (2005); Hegazi and Oguer (2000); Treder et al. (2004) and Hogue et al. (2005) obtained similar results.

4.2. Vegetative growth

The highest shoot development was determined in 1st irrigation program with frequent irrigation and lower values were obtained from 3rd irrigation program with less irrigation water amounts. That is, the vegetative development was effected negatively as irrigation interval increased. Frequent irrigation of apple trees had positive effects on the vegetative development (Çay et al., 2009; Uçar et al., 2009), less water or water stress had negative effects on the vegetative development of apple trees (Lakso, 2003; Naor, 2006).

According to the results of shoot numbers, shoot length and shoot diameter in 2011, it was determined that the rose oil processing wastes, wheat straw and control treatments were generally in same group as statistically. Because the thicknesses of the wheat straw and rose oil processing wastes decreased in time, their effectiveness also decreased. This is why they had similar results. As synthetic mulch materials are more effective on the water preservation compared to organic mulches (wheat straw, rose oil processing wastes etc.), black textile was more effective on the vegetative development of the trees.

Leaf area index (LAI)

Leaf area measurements is important as for monitoring the plant development (Kılıç and Anaç, 2005) as the leaves are a very important stress indicator for plants (Kocaçalışkan, 2005). Therefore, leaf area index is also important indicator for plants. The highest leaf area index ~~were~~ **was** obtained from mulch treatments and 1st irrigation program. The treatments with a greater leaf area index may be recommended as it is also a good indicator of plant development. Young apple trees growth continuously. So they had more leaf and also leaf area for each tree. Cohen and Naor (2002) determined that average LAI of Golden Delicious apple variety grafted on M9 rootstock M9 was 2.4 m² m⁻². Uçar et al. (2009) reported that the values of Galaxy Gala and Top Red apple varieties grafted on M9 rootstock ranged between 0.11 and 0.94 m² m⁻². Because of different apple variety, rootstocks and planting distances used in the study, values were different from this study.

Trunk cross-sectional area (TCSA)

According to results of TCSA values obtained from the study, it was observed that these values were continuously increasing each year after planting. Black textile had the highest values and the lowest values were obtained from the control treatment. Shoot development of fruit trees increased at young apple orchard when mulch materials were used and this increasing affected positively to trunk diameter increasing (Buban et al., 1996). Also frequent irrigation had a positive effect on trunk cross-sectional area. It is possible to said that the vegetative development increased in 1st irrigation program with more frequent irrigation. Vegetative development of fruit trees decrease when soil water at effective root zone of trees decreases (Uçar et al., 2009). Vegetative development was negatively affected as the irrigation interval increased (for 3rd irrigation programs). Yazgan et. al. (2004) for young sweet cherry trees and Uçar et. al. (2009) for young apple trees also reported similar results.

Water saving was determined in the study and less irrigation water was used for apple growing without a negative effect on vegetative development. Strong vegetative development has a positive

effect when the trees grown up to yield age. Vegetative development (shoot number, shoot length, shoot diameter, trunk cross-sectional area, leaf area index) increased continuously because apple trees were young. Vegetative development of apple trees in mulch treatments was higher than apple trees in control treatments. Black textile among mulch materials had the highest vegetative development. Rose oil processing wastes and wheat straw mulches generally had similar results. Researchers reported that mulch materials increased shoot diameter, shoot length and shoot numbers of fruit trees (Kviklys et al., 2004; Phadung et al., 2005). The soil water was preserved at effective root zone for a longer period with mulch materials. Therefore, apple trees spent less energy during water intake with their roots (massive water intake) and as a result they had a higher vegetative growth and development. Neilsen et. al. (2003) and Hogue et. al. (2005) obtained similar results.

It was determined that mulching and irrigation programs had both positively effects on vegetative development and water saving for young apple orchards. Irrigation is recommended when %20 of available water holding capacity at effective root zone (0-90 cm) is consumed (1st irrigation program) for young apple trees grafted on MM106 rootstock. Recommended irrigation is the 1st irrigation program when the available water resources are sufficient. In addition, apple growers can use 2nd irrigation program together with mulch materials when water resources are scarce. 22.0 and 31.3% in average water saving was obtained in mulch treatments. The highest water saving values were determined in black textile treatments as 23.5-31.3%. Accordingly, irrigation for more agricultural area may be provided with mulch using when water resources are also sufficient. Irrigation interval could be expanded with mulch using and a reduction of labor, energy cost etc. cost items was occurred by using less water. At the orchards where organic mulch materials such as wheat straw and rose oil processing wastes are used; completion of the missing thicknesses may be recommended at the end of every growing season to continue the effectiveness of mulches. According to the current status or at the regions where water resources are limited; the mulch and irrigation programs determined with this study may be recommended to apple growers.

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REFERENCES

- Barragan, J., & Wu, I. P. (2001). Optimal scheduling of a micro irrigation system under deficit irrigation. *Journal of Agricultural Engineering Research*, 80 (2), 201-208.
- Buban, T., Helmeczi, B., Papp, J., Dorgo, E., Jakab, I., Kajati, I. & Merwin, I. (1996, July). *IFP-compatible ground-cover management systems in a new-planted apple orchard* Paper presented at the Proceedings of 19th International Conference on Integrated Fruit Production, 19(4), 263-267, Crackow, Poland.
- Cohen, S. & Naor, A. (2002). The Effect of three rootstocks on water use, canopy conductance and hydraulic parameters of apple trees and predicting canopy from hydraulic conductivity. *Plant, Cell and Environment*, 25(1), 17-28.
- Çay, Ş., Tarı, A. F., Dinç, N., Bitgi, S., Özbahçe, A., Palta, Ç., & Okur, O. (2009). Effects of different irrigation programmes on yield and quality characteristics of Granny Smith apple variety grafted onto M9 rootstock. *Journal of Agriculture Sciences Researches*, 2(2), 73-79.
- FAO, (2019). Food and Agriculture Organization Statistics. <http://www.fao.org/faostat/en/#data/QC>. Erişim tarihi: 12.02.2020
- Hegazi A. & Ogier, J.P. (2000). Plastic mulching for weed control and water economy in vineyards. *Acta Horticulturae* 2000, (536,) 245-250.
- Hogue, E. J., Kuchta, S., Neilsen, G. H., Forge, T. & Neilsen, D. (2005, June). *Improving yield and soil quality with mulches and amendments in orchards* Paper presented at the Proceedings of the Third National Organic Tree Fruit Research Symposium, 6-8 June 2005, p. 76-77, Campbell's Resort, Chelan, WA.
- James, L.G. (1988). *Principles of Farm Irrigation System Design*. John Wiley and Sons Inc., New York, USA.

- Kanber, R. (2002). *Irrigation*. Çukurova University Agriculture Faculty General Publication Number:174, Lesson books No: A-52, Adana, 530 p.
- Kılıç, C., & Anaç, D. (2005, October). *The relationship between potassium fertilization and physiological parameters of satsuma mandarine under salt stress* Paper presented at the Workshop on Potassium, 3-4 October 2005, p. 188-195, Eskişehir, Turkey.
- Kocaçalışkan, İ. (2005). *Plant Physiology*. 5th ed. Academic Pres, Dumlupınar University, Kütahya-Turkey, 318 p.
- Küçükyumruk, C., & Ay. Z. (2010, June). *Meyve yetiştiriciliğinde yüzey sulama yönteminden damla sulama yöntemine geçişte yapılan hatalar ve çözüm yolları* Paper presented at the 1. Ulusal Toprak ve Su Kaynakları Kongresi, 1-4 Haziran 2010, Eskişehir, (sözlü bildiri), Bildiriler kitabı, s: 232-237.
- Kviklys, D., Rumpunen, K., & Ruusa, S. (2004). Mulching systems and weed control in Japanese Quince (*Chaenomeles japonica* LDL.) Plantations. *Journal of Fruit and Ornamental Plant Research*, 12, 125-132.
- Lakso, A. N. (2003). *Water Relations of Apples*. p. 67-194. In Apples, CABI Publishing, Cambridge, USA. ISBN 0 85199 592 6.
- Li, S. X., Wang, Z. H., Li, S. Q., Gao, Y.J. & Tian, X.H. (2013). Effect of plastic sheet mulch, wheat straw mulch, and maize growth on water loss by evaporation in dry land areas of China. *Agricultural Water Management*, 116, 39-49.
- Naor, A. (2006). Irrigation scheduling and evaluation of tree water status in deciduous orchards. In: Janick, J. (Ed.), *Horticultural Reviewers*, 32, 111-165.
- Naor, A., Naschitz, S., Peres, M. & Gal., Y. (2008). Responses of apple fruit size to tree water status and crop load. *Tree Physiology*, 28, 1255-1261.
- Neilsen, G., Hogue, E.J., Forge, T., & Neilsen, D. (2003). Mulches and biosolids affect vigour, yield and leaf nutrition of fertigated high density apple. *Hortscience*, 38(1), 41-45.
- Önder, S., Kanber, R., Önder, D., & Kapur, B. (2005, September). *The differences of possibility of global climate changing on irrigation methods and management techniques*. Paper presented at the GAP IV. Congress of Agriculture, 21–23 September 2005, p. 1128-1135. Şanlıurfa.
- Phadung, T., Nilnond, S., Phavaphutanon, L., & Thongpae, S. (2005). *Effects of irrigation and mulching materials on growth, yield and berry quality of "Perlette" grape* Paper presented at the Proceeding of 43rd Kasetsart University Annual Conference, p. 459-466. Thailand, 1-4 Feb., 2005.
- Treder, W., Klankowski, K., Mika, A., & Wojcik, P. (2004). Response of young apple trees to different orchard floor management systems. *Journal of Fruit and Ornamental Plant Research*, 12, 113-122.
- TUİK, 2019. TUİK Türkiye İstatistik Kurumu. <http://www.tuik.gov.tr/UstMenu.do?metod=temelist>. Erişim tarihi: 12.02.2020
- Uçar, Y., Kadayıfçı, A., Aşkın, M.A., Kankaya, A., Şenyiğit, U., & Yıldırım, F. (2009). *The Effect of Different Irrigation Programs On Vegetative and Reproductive Growth Parameters of Young Dwarf Apple Varieties* (final report). Project number: TUBİTAK-TOVAG 105-O-538, 197 p.
- U.S. Salinity Laboratory Staff (1954). *Diagnosis and Improvement of Saline and Alkaline Soils*. Agricultural Handbook No: 60.
- Ünlü, M. (2000). *Determining of water consumption of cotton and crop coefficients by micrometeorological methods in Çukurova conditions* (PhD). Çukurova University Natural Applied Science.
- Yazgan, S., Büyükcangaz, H., Demirtaş, Ç., & Candoğan, B. N. (2004). The effects of different irrigation programme on vegetative development parameters and plant water consumption in young sweet cherry trees. *Uludağ University Agriculture Faculty Publication*, 18(2), 1-12.
- Yıldırım, O. (2005). *Irrigation Systems Design*. Ankara University Agriculture Faculty Publications: 1542, Lesson Book:495, Ankara, 348 p.
- Zambreno, K., Hoover, E., Poppe, S. & Proppom, F. (2005, June). *Organic mulches affect soil moisture and temperature during establishment of apple trees* Paper presented at the Proceedings 3rd National Organic Tree Fruit Research Symposium. June 6-8, 2005, p. 74-75. Chelan, Washington. Washington State University Tree Fruit Research and Extension Center, Wenatchee, WA. In: Granatstein, D. and A. Azarenko (eds.).