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THE EFFECTS OF DIFFERENT BIODEGRADABLE MULCHES ON WEED POPULATION AND FRUIT YIELD IN WATERMELON PRODUCTION FIELD

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Abstract

The purpose of this study was to investigate the effects of various biodegradable mulch materials on watermelon (*Citrullus lanatus*) yield and weed control over two consecutive crop seasons in Iğdır, Türkiye (2019-2020). Crimson Sweet, the region's most widely cultivated watermelon variety, was used. A randomized complete block design with 9 treatments and 4 replications was used for the experiment. Organic mulch materials included oat straw, peat, sawdust, fresh lawn clippings, decayed lawn clippings, flax, and felt. Each block had two distinct controls, a weedy and a weed-free (hoeing) treatment. The researchers looked into the effects of mulch materials on weed control, fruit yield (kg/da), average fruit weight (kg), fruit diameter (cm), and soluble solids concentration (SSC - percent brix). *Chenopodium album, Amaranthus retroflexus, Heliotropium europeum, Chenopodium botrys,* and *Atriplex hortensis* were the top five weeds with the highest density. The most effective mulch materials in terms of weed control were obtained from flax cover and felt applications in both years of the study, where weed growth was not observed in these parcels. The weed-free parcel produced the highest yield in both years. The weed-free parcels produced the highest yield in both years, 5.339 tons/da in 2019 and 4.839 tons/da in 2020. Fresh lawn clipping (3.718 tons/da) and oat straw (3.434 tons/da) yielded the highest yields after weed-free treatments in 2019. The same treatments were found to provide the two highest yields in the second year experiments, but in reverse order: oat straw (4.309 tons/da) and fresh lawn clipping (4.193 tons/da). Similarly, the weed-free parcels had the highest fruit weight, fruit diameter, and SSC. Fresh lawn clipping and oat straw treated parcels produced the second and third best results for each test parameter. Aside from these treatments, all other mulch applications yielded significantly better results than the weedy parcels, indicating that mulch applications are very beneficial in controlling weeds and improving fruit yield and quality.

Key words: *Citrullus lanatus*, Oat straw, Fresh lawn clippings, Organic mulch materials, Weed control.

Introduction

Watermelon (Citrullus lanatus), a Cucurbitaceae family member, is a spherical or cylindrical summer vegetable with broad branches (Wehner, 2008; Abu-Nasser & Abu-Nasser, 2018). It is an exotic fruit that contains nutrients and phytochemicals which have been shown to be beneficial to human health (Choudhary *et al*., 2015). Watermelon fruit also contains vitamins B, C, and E, as well as minerals such as phosphorus, magnesium, calcium, and iron (Romdhane *et al*., 2017). Watermelon fruit has been shown to enhance intestinal and kidney health, soften the skin, refresh the body, and aid digestion, as well as reduce the severity of skin diseases, and watermelon seeds to lower high blood pressure and stop bleeding (Abu-Nasser & Abu-Nasser, 2018).Watermelon is grown in many countries around the world, and it is the most cultivated plant (around 100 million tons) among cucurbits. China is the leading producer of watermelons, accounting for nearly 60 percent of global output. In terms of total production, Türkiye, India, and Brazil trail China (Anon., 2021). With the rapid increase in the world's population, there is an increasing demand for horticultural crops to meet humanity's nutritional needs (Foley *et al*., 2011). Almost all lands suitable for horticultural production are now in use, and it is extremely difficult to expand horticultural lands. Thus, increasing plant yield is the only way to increase production while meeting consumer demand (Demirbaş & Atış, 2005). However, a number of factors reduce crop production efficiency in horticultural areas. Weed problems are one of the most important critical factors (Swinton & Van Deynze, 2017). Weeds cause significant crop losses and damage in horticultural areas (Oerke, 2006; Gharde *et al*., 2018). Weed presence and competition among weeds and crops, particularly under water stress conditions, cause a significant reduction in crop yields of up to 50% (Abouziena *et al*., 2014). Weeds are among the most damaging pests of agricultural crops, reducing crop yields while also severely affecting crop quality (Reddiex *et al*., 2001; Szekelyne, 2001; Jabran & Chauhan, 2018). Manual weeding in cucurbits is difficult because the shallow root system overgrows with weed roots, making damage unavoidable if manual weeding is neglected (Bucki & Siwek, 2019). Mulching is thus an efficient and risk-free method (Abouziena & Haggag, 2016). Given the rapid growth of cucurbits, mulch use is critical for weed control, especially early in the growing season when the soil is not completely covered by crops (Bucki & Siwek 2019).Chemical control with herbicides is now the most popular method due to the quick results, ease of application, and low cost (Kitiş, 2011). However, incorrect and intensive weed control herbicide use (Bo *et al*., 2017; Su, 2020) causes serious environmental and ecological problems (Sardana *et al*., 2017). Herbicide residues in groundwater, soil, and foods pose a risk to humans (Taylor *et al*., 2002; Sharma *et al*., 2017; Ugbede, 2019). Furthermore, incorrect and excessive herbicide use leads to weed resistance (Powles & Yu, 2010; Mortensen *et al*., 2012; Kraehmer *et al*., 2014; Bo *et al*., 2017; Heap & Duke, 2018; Peterson *et al*., 2018; Heap, 2022). Mulching is an alternative method of weed control that eliminates the negative side effects of agrochemicals. Various living or non-living materials are used to cover the soil surface in this method to reduce moisture loss and weed population while increasing crop yield (Nalayini, 2007; Kader *et al*., 2019). Mulches have the potential to reduce water runoff, increase soil infiltration capacity, limit weed populations through shading, and act as evapotranspiration barriers (Rathore *et al*., 1998). Mulch acts as a barrier to the passage of light across the soil surface, resulting in reduced germination of small-seeded weed species (Iqbal *et al*., 2020). Mulches also act as physical barriers to weed growth (Ahmad *et al*., 2015; Ahmad *et al*., 2020).Rapid industrialization and urbanization have resulted in rising global temperatures over the years, destabilizing global agro-ecological systems. As a result, new environmentally friendly horticultural practices are required for long-term food production (Iqbal *et al*., 2020). Furthermore, water availability has been rapidly decreasing in recent years as a result of climate change, population growth, and pollution of fresh water resources by heavy metals and other pollutants. In addition to water scarcity, land resource degradation is on the rise, necessitating simple and cost-effective solutions. Mulches play an important role in helping modern horticultural production systems achieve their sustainability goals. It is also critical to choose the best type of mulch for the job, taking into account the soil type, environmental conditions, crop, and specific goals for which the mulch will be used (Jabran, 2019).In this respect, mulching is one of the most successful weed control methods that can be an alternative to chemical control and achieve the sustainability goal of production systems. The main purpose of this study was to test the impacts of different mulch materials on the weeds in watermelon fields and to determine their effects on yield in order to ensure sustainability without damaging the ecosystem and reduce producer costs.

Materials and Methods

This research was conducted at Iğdr University's Şehit Bülent Yurtseven Campus in 2019-2020. Iğdır is located between 39° 39' and 40° 07' North latitudes and 43° 17' and 44° 49' East longitudes. The watermelon cultivar Crimson Sweet was used in the study. In the current study, seven different mulching materials were used, along with weedy and weed-free controls. Table 1 shows the application amounts and general properties of the mulch materials used in the study.

The soil at study area was a sandy loam characteristic with a pH of 7.8 and some other properties of the soil are: lime (8%), P_2O_5 (0.7 kg/da), K_2O (0.8 kg/da), organic matter (0.6%), nitrogen (0.12 kg/da), EC (280 micromhos/cm). Table 2 contains the region's climatic data.

The experimental set-up, watermelon planting and crop care: The study was set up in a randomized complete block design in both years (2019 and 2020), with 9 treatments (7 mulch materials, 1 weed-free and 1 weedy parcel) and 4 replications. Each parcel has an area of 8 m2 (4 x 2 m), with a security strip (1.5 m) between them and a distance of 0.5 m between the rows. The experimental studies took up a total of 525 m2. Watermelon seedlings were transplanted into annealed soil on the 13th of May in both years, with 80 cm between rows and 50 cm between rows. Per decare, 4-6 tons of barnyard manure were applied prior to planting. The first irrigation was done with a drip irrigation system after the seedlings were planted. Watermelon irrigation was then performed once a week. Mulch materials were laid in the parcels after planting and the initial irrigation. Each character was made up of 16 watermelon seedlings. In the event of weed emergence, hoeing and hand plucking were performed in the weed-free parcels. No treatment was applied to the weedy parcels, and they were left alone.

Table 1. Treatments (mulching materials) used in the research, application rates and general characteristics.

Treatmets	Application rates	General characteristics
Oat straw	3,750 kg/da	Chopped into bales
Felt		Produced from the breed wool of purple Karaman sheep. Width: 2 m, length: 4 m and thickness: 1 cm
Flax		Width: 2.20 m and length: 4 m
Peat		It has a fibrous structure and the pH is in the range of 5.5 - 6.5.
Fresh lawn clipping	4,375 kg/da	Consist of 50% *Festuca arundinacea,* 35% *Lolium perenne* and 15% *Poa pratensis*
Decayed lawn clippings	6,250 kg/da	Consist the same ratio of fresh lawn clipping treatment but was waited for 1 week and decayed before using
Sawdust	2,500 kg/da	Sawdust waste of poplar wood

Table 2. Temperature, rainfall and humidity data of the region during 2019-2020 and long term (1941-2020) averages (MGM, 2021).

Months	Average temperature (°C)			Total rainfall (mm)			Average relative humidity (%)		
	2019	2020	Long term	2019	2020	Long term	2019	2020	Long term
March	6.8	10.44	6.2	23.5	18.1	22.1	69.6	65.6	52.2
April	12.1	11.49	13	25.1	83.6	33.8	66.6	76.6	49.9
May	19.9	18.80	17.7	25.9	76.1	46.5	58.1	63.1	51.5
June	25.6	24.19	22.1	13.6	15.7	32	51.6	48.3	47.3
July	27.3	26.7	25.9	0.6	30.2	13.7	44.2	48.4	45.3
August	27	24.2	25.3	0.6	15.3	9.7	46	47.6	47.1
September	19.9	23.5	20.4	15.4	1.4	11.5	62	47.7	46.2
October	15.8	14.5	13.1	4.5	7.3	26.3	66	49.6	48.53

Observation of the impacts of mulching on weeds: Weeds were counted on a species basis prior to harvest in both years to determine the weed species in the experimental area. Individual weed species densities (plants/m^2) were calculated by dividing the total number of plants in m^2 by the total area (Odum, 1971; Özdemir & Doğan, 2020). The weeds in each plot were then cut from the soil surface separately, placed in paper bags, and transported to the Herbology Laboratory. After being kept in a 70°C oven for 24 hours in the laboratory, their dry weights were determined and recorded one by one.

Evaluation of yield and yield elements: Watermelon fruits were harvested on 05^{th} of September in both years. Average fruit weight (kg) and fruit yield (kg/plant) were calculated and recorded. Then, the yield was transformed to ton/da for a better comparison and economic analysis of the data. Afterwards, 10 watermelon fruits belonging to each parcel were put into bags and taken to the laboratory for further analysis. The fruit diameter (cm) and soluble solids concentration (SSC - %) of the fruits were then determined and recorded.

Statistical Analyses

All raw data of the experiments, including fruit weight, fruit diameter, SSC and yield together with the dry weight of the weeds were applied in SPSS 17.0 Package Program. Duncan multiple range test (at 5% significance level) was applied to the data after ANOVA for comparison of the impacts of different treatments on the study parameters.

Results and Discussions

Weeds in the experimental site: In 2019, 17 weed species from 9 families (1 narrow-leaved and 8 broad-leaved) were identified, and 15 weed species from 8 families (1 narrow-leaved and 7 broad-leaved) were observed in 2020. Chenopodium album L., *Amaranthus retroflexus* L., *Heliotropium europaeum* L., *Chenopodium botrys* (L.) Pers., and *Atriplex hortensis* L. are the first five weed species with the highest density in both years. Furthermore, among the nine families identified, Amaranthaceae (6) and Poaceae (4) ranked first in terms of weed numbers. Weed species detected in the experimental area during the study's years are similar to Tepe (1998), where *A. retroflexus, C. album, P. oleracea, C. dactylon,* and *S. arvensis* are the most common. Table 3 displays the families, scientific names, common names, life cycles, and density (plant/m^2) of weed species detected in the experimental area in 2019 and 2020.

For two years, Duncan's multiple comparison test was used to determine the effect of different mulch materials on weed dry weights in watermelon plantations. According to the research results, there is a statistical difference in weed dry weights between mulch applications in 2019 (F=20.125 and P=0.000.01) and 2020 (F=77.64 and P=0.000.01) (Table 4).

Table 3. Weed species found in the experimental area in both years.

Family	Scientific name	Common name	Life cycle	Density (plant/m^2)	
	Narrow-leaved (monocots)			**2019**	**2020**
Poaceae	*Cynodon dactylon* (L.)	Bermuda grass	P	3.80	3.50
	Echinochola colonum (L.)	Jungle rice	A	3.50	3.40
	Sorghum halepense (L.) Pers.	Johnsongrass	P	1.75	0.60
	Phragmites australis (cav.)	Common reed	P	1.02	0.75
	Broad-leaved (dicots)				
Amaranthaceae	*Chenopodium album* L.	Common lambsquarters	A	**32.15**	**25.2**
	Amaranthus retroflexus L.	Redroot pigweed	A	**12.16**	**19.60**
	Chenopodium botrys (L.) Pers.	Sticky goosefoot	A	**6.29**	**7.02**
	Atriplex hortensis L.	Garden orache	A	**6.12**	**5.30**
	Amaranthus blitoides S. Watson	Pigweed	A	2.85	3.02
	Salsola ruthenica ILJIN	Salsola	A	0.02	-
Asteraceae	*Sonchus oleraceus* L.	Common sowthistle	A	0.14	0.01
Brassicaceae	*Sinapis arvensis* L.	Wild mustard	A	2.92	3.02
Convolvulaceae	*Convolvulus arvensis* L.	Field bindweed	P	0.16	0.30
Heliotropiaceae	*Heliotropium europaeum* L.	European heliotrope	A	**8.50**	**5.20**
Malvaceae	*Abutilon theophrasti* Medicus	Velvet leaf	A	2.64	0.47
	Malva sylvestris L.	Common mallow	P	0.02	-
Polygonaceae	*Polygonum aviculare* L.	Common knotgrass	A	0.01	-
Portulacaceae	*Portulaca oleracea* L.	Common purslane	A	4.26	2.50

Life Cycles; P: Perennial and A: Annual

Table 4. Weed dry weights of watermelon parcels under the effects of nine treatments in 2019 and 2020.

Treatments	Year 2019	Year 2020
Felt	0.00 a	0.00 a
Flax	0.00 a	0.00 a
Weed-free	0.00 a	0.00 a
Oat straw	37.02 b	23.27 b
Sawdust	45.02 b	28.02 b
Fresh lawn clippings	44.12 b	29.75 b
Peat	117.00 c	93.25 c
Decayed lawn clippings	238.25 d	270.00 d
Weedy	466.25 e	480.00 e

Same letters next to the values in the above table represents no significant difference among the treatments according to Duncan's multiple range test at the 0.05 level

Comparison of the impacts of mulch materials on weed management in both years showed that, there was no weed emergence in the felt and flax parcels. In the study, oat straw (37.02 g), fresh lawn clipping (44.12 g) and sawdust (45.02 g) mulch applications were included in the same statistical group after the weed-free, felt and flax parcels both in 2019 and 2020. The highest weed dry weight was obtained in the decayed lawn clipping (238.25 g) parcels in both years after the weedy parcels. In the second year, the highest weed dry weights after the weedy parcels were obtained from the decayed lawn clipping (270.0 g) and peat (93.25 g) mulch parcels. In both years of the study, weed control applications had higher weed dry weights compared to all mulch materials. Johnson *et al*., (2004) stated that the straw mulch materials used in their study on watermelon suppressed weeds. This result is in parallel with the current results. Most studies report that mulches can effectively control weeds. Temel *et al*., (2019) similarly stated that weeds could be controlled with straw mulch. Mulch application in agricultural areas can help suppress weeds, in whole or in part (Hammermeister, 2016; Abouziena & Haggag, 2016) as seen in the current study where felt and flax suppresses full weeds but other mulch materials suppresses weeds partially.

Duncan's multiple comparison test was used to determine the effect of different mulch materials on fruit weight, fruit diameter, SSC and yield in watermelon cultivation for two years. According to the results of the statistical analysis, among the mulch applications, in terms of fruit weights in 2019 (F=35,305 and P=0.00<0.01) and in 2020 (F=29.42 and P=0.00<0.01), in terms of fruit diameter in 2019 (F=14,085 and P=0.00<0.05) and in 2020 (F=14.611 and P=0.00<0.01), in terms of SSC in 2019 (F=4.127 and P=0.003<0) .01) and in 2020 (F=6.347 and P=0.00<0.01) and finally in terms of yield in 2019 (F=16.922 and P=0.003<0.01) and in 2020 (F=13.541 and P=0) ,00< 0.01) statistically significant difference was observed at 5% significance level (Table 5).

The weed-free (hoe) treatment produced the most fruit weight in both years of the study, with 7.4 kg in the first year and 7.3 kg in the second. The fresh lawn clipping (5.9 kg) treatment had the second highest fruit weight in 2019, followed by oat straw (5.0 kg) and flax (4.9 kg) parcels. Furthermore, the decayed lawn clipping parcels (3.5 kg) had the lowest fruit weight of watermelon among the mulch materials, excluding the control parcels (2.5 kg). The highest fruit weights were obtained in the second year from oat straw (6.5 kg), fresh lawn clipping (6.3 kg), flax (5.6 kg), and felt (5.4 kg) parcels, excluding weed-free (hoe) control parcels (7.3 kg). In 2020, the decayed lawn clipping (3.64 kg) parcel had the lowest fruit weight, excluding the control parcel. In both years of the study, the weedy control parcels had the lowest fruit weight averages. Furthermore, the average total fruit weight by year in 2019 was 4.5 kg and 5.3 kg in 2020. Andino & Motsenbocker (2004) and Nergiz (2011) found a statistical difference in watermelon weight between different mulch materials in similar studies.

The highest fruit diameter was obtained in weed-free (hoe) control (22.90 cm), and was followed by oat straw (21.40 cm) and fresh lawn clipping (21.17 cm) parcels in 2019. In the second year of the study, similar to the first year, the highest fruit diameter was obtained from weed-free control parcel (22.50 cm), and was followed by oat straw (22.25 cm), fresh lawn clipping (21.60 cm) and flax (21.25 cm) parcels. The lowest fruit diameter among mulch materials was obtained in decayed lawn clippings parcels (19.4 cm and 19.5 cm) in both years of the study. The most inferior fruit diameter was obtained in the weedy control parcels in both years of the study. In addition, the average fruit diameter by years was determined as 20.2 cm in the first year and 20.6 cm in the second year. Ekinci & Dursun (2009) conducted a study for two-year (2003-2004) experiments and stated that the highest values in watermelon diameter were obtained from mulch materials as 19.5 cm and 18.4 cm for Maxi Crimson cultivar in 2003 and 2014, respectively. These results are in parallel with the current study for mulch materials. However, Andino and Motsenbocker (2004) in their study, reported that the effects of different mulch materials on fruit diameter in watermelon were statistically insignificant.

During the study years, the highest fruit SSC was obtained in 2020 from the weed-free (hoe) parcel (10.9%). In the first year of the study, two fruits grown in two different treatments showed higher than 10% SSC. These treatments were weed-free control (10.7%) and felt (10.4%). In the second year, six treatments were found to provide higher than 10% of SSC. These treatments are weed-free control (10.9%), oat straw (10.6%), felt (10.6%), Fresh lawn clipping (10.0%), flax (10.0%) and sawdust (10.00%). The lowest SSC scores were noted for the weedy parcel (8.7%) and peat parcels (9.37%). In addition, the lowest SSC values were obtained in weedy plots in both years. Average SSC by years were 9.35% in the first year, and 9.8% in the second year. Farias-Larios & Orozco-Santos (1997) stated that SSC was not affected by mulch applications as a result of their research. However, in another study, Nergiz (2011) reported that SSC vary in the range of 10-11%, which are in accordance with the findings of the current study.

Table 5. The effects of mulch materials on watermelon fruit weight, fruit diameter, fruit SSC and yield in 2019 and 2020.

Treatments	Fruit weight (kg)		Fruit diameter (cm)		Fruit SSC (%)		Yield (tons/da)	
	2019	2020	2019	2020	2019	2020	2019	2020
Fresh lawn clipping	5.9 b	6.3 bc	21.2 b	21.6 ab	8.7 cd	10.0 abc	3,718 b	4,193 b
Decayed lawn clipping	3.5 e	3.6 f	19.4 de	19.5 d	9.3 bc	9.8 c	2,392 c	3,007 e
Felt	3.6 de	5.4 d	19.6 de	20.2 cd	10.4 ab	10.6 ab	2,065 c	3,715 bc
Sawdust	4.3 cd	4.9 de	20.0 bcd	19.9 d	9.7 abc	10.0 abc	2,859 bc	3,584 cd
Flex	4.9 c	5.6 cd	20.7 bc	21.3 abc	9.5 abc	10.0 abc	2,465 c	3,665 c
Peat	3.5 e	4.3 ef	20.7 bc	20.8 bcd	8.8 cd	9.4 c	2,322 c	3,022 de
Oat straw	5.0 c	6.5 b	21.4 b	22.3 a	9.4 abc	10.6 ab	3,434 b	4,309 ab
Weedy	2.5 f	3.5 g	16.7 f	17.6 e	8.0 d	8.3 d	1000 d	2,400 f
Weed-free	7.4 a	7.3 a	22.9 a	22.5 a	10.7 a	10.9 a	5,339 a	4,839 a

Same letters next to the values in the above table represents no significant difference among the treatments according to Duncan's multiple range test at the 0.05 level

In both years of the study, the highest watermelon yields were obtained in the weed-free control (hoe) parcels, with values of 5,339 tons/da in the first year and 5.839 tons/da in the second year, which resembles with the finding of Adamović *et al*. (2021) that the highest fruit yield of watermelon was obtained in control without mulching had significantly higher than mulching. After the weed-free control parcel, the highest watermelon yield was recorded from the fresh lawn clipping (3,718 tons/da), oat straw (3,434 tons/da) and sawdust (2,859 tons/da) in 2019, and oat straw (4,309 tons/da) fresh lawn clipping (4,193 tons/da), flax (3,665 tons/da) and sawdust parcels (3,584 tons/da) in 2020. The watermelon yields were lowest in the sawdust parcel among all mulch materials in the current study were similar to what Regmi *et al*., (2021) found in summer squash, among other mulching materials. The lowest watermelon yields were obtained in felt parcel (2,065 tons/da) in the first year and decayed lawn clipping parcel (3.007 tons/da) in the second year. In both years, in terms of watermelon yield, all mulch materials were more productive than weedy control parcels, which resembles with the finding of Alptekin & Gürbüz (2022) who found the lowest cucumber yield in weedy check plots. In addition, there is an increase in watermelon yield in the second year as compared to the first year, and the average watermelon yield in the first year was 2,844 tons/da, while it was 3,733 tons/da in the second year. Sun *et al*. (2014) stated in their study that all mulch, row mulch, and root mulch applications increased the watermelon yield by 24.8%, 11.5% and 15.1%, respectively. In another study, Singh *et al*., (2019) reported that different mulch materials in watermelon increased the yield of watermelon compared to the control parcels. Similar results were reported by Bozhüyük *et al*., (2022) in tomato. The results of the two studies and the results of the current study are in agreement. The higher yield was obtained in all mulch materials, especially when compared to weedy control parcels, where there was a difference in watermelon yield between mulch materials.

Conclusions

In both years of the study, the most effective mulch materials for weed control were noted as the flax and felt applications, and no weed growth was observed in these treatments. After these two mulch materials, the lowest weed dry weights were obtained in oat straw and fresh lawn clipping parcels. Both flax and felt can be easily obtained and used for mulching in watermelon cultivation. Some of these materials are generally not used in horticultural systems and thrown as garbage, in which their production and use as mulch material would make a serious contribution to the country's economy. In both years, in terms of watermelon yield, all mulch materials were more productive than weedy control parcels. The mulch materials used in this research can also be used as materials in organic farming. In addition, it is thought that it will be useful to determine the effects of these mulch materials on soil structure and fertility in future studies.

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