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Effects of Different Polyethylene Mulch Colors on Greenhouse Cucumber Cultivation

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ABSTRACT
In this study, effects of blue and black polyethylene mulches used together with drip irrigation on yield of Yağmur cucumber cultivar were investigated under greenhouse conditions and mulching treatments were compared with unmulched drip irrigation treatments. Experiments were conducted in a polycarbonate greenhouse in Kayseri province of Turkey in 2019. Throughout the growing season, 655 mm irrigation water was applied in drip+mulch treatments and 776 mm in unmulched drip irrigation treatments. Although 16% less water was applied in drip+mulch treatments, 37% more yield was obtained from drip+blue mulch treatments and 34% more from drip+black mulch treatments. The highest cucumber yields per decare (12296.7 and 11783.6 kg) were respectively obtained from drip+blue mulch and drip+black mulch treatments and the lowest (7771 kg) from unmulched drip irrigation treatments. The highest weed dry biomass (88.42 g m-2) was obtained from unmulched drip irrigation treatments. While the effects of mulching treatments on weed biomass were found to be significant as compared to unmulched treatments, blue and black mulches were not significantly different.

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Farklı Renklerdeki Polietilen Malçların Serada Hıyar Yetiştiriciliği Üzerine Etkileri

ÖZET
Bu çalışmada damla sulama ile kullanılan mavi ve siyah polietilen malçların Yağmur sırık hıyar çeşidinin verimi üzerine etkileri araştırılmış, malçsız damla sulama konuları ile kıyaslanmıştır. Deneme Kayseri iklim şartlarında, 2019 yılında polikarbon serada yürütülmüştür. Mevsimlik su uygulamaları malçlı ve malçsız konularda sırasıyla 655 ve 776 mm olarak ölçülmüştür. Damla sulama+malçlı konulara verilen sulama suyu miktarları malçsız damla sulama konusuna göre yaklaşık %16 daha az olmasına rağmen verim değerleri damla sulama+mavi malç konusunda %37, damla sulama+siyah malç konusunda ise %34 daha fazla bulunmuştur. En yüksek dekara hıyar meyve verimleri mavi ve siyah malç konularında sırasıyla 12296.7 ve 11783,6 kg, en az ise 7771 kg ile malçsız damla sulama konusundadır. Çalışmada en yüksek yabancı ot kuru biyoması malçsız damla sulama yapılan parsellerden 88.42 g m-2) elde edilmiştir. Malç uygulamaların yabancı ot biyomasına etkileri malçsız konuya göre istatistiki olarak önemli iken, malçlı konular kendi arasında istatistiki olarak farklı bulunmamıştır.

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INTRODUCTION

Vegetables play a key role in human diets. Therefore, humans should consume vegetables regularly for a healthy life. Cucumber is highly rich in iron and calcium minerals and vitamins A, B, C and K. With a rich vitamin B content, it helps to protect emotional and mental health. About 95% of cucumber is composed of water, so it helps to remove toxins from the body easily. It relieves bad breath, moisturizes the body, and meets most of the daily vitamin needs. It is beneficial against high blood pressure. It has diuretic and laxative characteristics. It regulates blood pressure. It is highly rich in fiber. It prevents indigestion by contributing to the digestive system. It is also a good tonic for liver, kidneys and gall bladder (Şalk et al., 2008).

Cucumber is among widely produced vegetables in the world and in Turkey. With about 88 million tons of annual production in 2019, cucumber was ranked as the 5th vegetable in the world (Anonymous, 2021a). In Turkey, annual cucumber production was 1 886 239 tons in 2020 and with this value, it is the third vegetable produced after tomato and watermelon (Anonymous, 2021b).

The increase in crop production is affected by three basic components: climate, soil and plant. There are other yield-increasing measures such as irrigation, good quality seeds, plant nutrition, pests and disease control and cultural practices (Delibaş, 1994). However, the role of irrigation in increasing yields is quite different as compared to others. Irrigation not only ensures yield increase, but also facilitates the effect of other agronomic practices on yield levels. For instance, expected yield increase with good quality seeds and fertilization can only be achieved if the proper irrigation was practiced (Delibaş, 1994). Today, pressurized irrigation methods are known as modern methods. Among the modern irrigation methods, drip irrigation offers both high irrigation efficiency and greater yield levels. In this method, supplementary mulch treatments are applied to increase water use efficiency, for weed control and ultimately to increase yields (Gerçek et al., 2017).

Mulch is an organic material such as straw, hay, sawdust, or an inorganic material such as plastic that covers the soil surface. Mulches prevent evaporation of irrigation water from the soil, thus increase irrigation water use efficiency and provide a constant moisture level around field capacity within the rootzone. Mulch also prevents weed development. Dark and dull-colored mulches generate a physical barrier over the soil surface, prevent intrusion of light into the soil, thus prevent germination and emergence of weeds (Jabran, 2019). Weeds often compete with the main plant and accelerate consumption of available plant nutrients and available soil water. Growers generally use agro-chemicals and hoeing for weed control. Chemical control increases production inputs and missuses often cause serious damage to environment, soil, and plant, and, therefore, to people.

Mulch covers increase soil temperature, thus have positive effects on soil microbial activities within the rootzone and plant growth. Such covers also allow irrigated farming in places with deficit water resources and offer a kind of crop insurance. Effects of plastic mulches of different colors on plants are quite different. Previous researchers indicated the effects of colors on yield. It was reported that colored plastic mulches had different effects based on season, location, and years (Csizinky et al., 1995). Black-colored mulches increased soil temperature more in spring season, white and aluminum-colored mulches in summer and autumn seasons, thus increased yield levels (Tarara, 2000). It was reported in a study conducted on tomato with black, gray, silvery, red, white mulches that different yield values were obtained in different seasons (Teasdale and Mohler, 2000).

In a previous study, effects of dark-colored paper and biodegradable plastic mulches on cucumber yield were found to be significant as compared to the control treatment without mulch and it was indicated that these mulches also prevented weed growth and development (Happala et al., 2015). Torres-Olivar et al. (2018) investigated the effects of mulches of different colors on pickling cucumber yield under field conditions and the highest yield per plant was reported as 4.88 kg for silver/black, 4.78 kg for aluminum/black, 4.51 kg for black, 3.86 kg for white/black mulches and 2.45 kg for control treatment without mulching. Researchers reported significantly greater nutrient concentration, soil temperature, yield, growth, and gas exchange values for mulching treatments than for the control treatment.

In this study, effects of blue and black mulches on yield and irrigation water use of cucumber (cv. Yağmur) grown in a greenhouse in summer season were investigated and comparisons were made with non-mulched drip irrigation method.

MATERIALS and METHODS

Study Area

Present research was carried out in 2019 in an east-west oriented, Venlo-type, anti-frost and heated polycarbonate greenhouse (9x18 m) over the experimental fields of Kayseri University Safiye Çıkrıkçıoğlu Vocational Collage.

Central Anatolian climate with cold and snowy winters and hot and dry summers is dominant in the region. Greenhouse indoor average temperature and

relative humidity values are provided in Table 1. Average temperatures varied between 13.3 - 24.7 °C and the relative humidity between 50 - 73%. Soil samples were taken from 0 - 30 cm soil profile. Soil analyses revealed that greenhouse soils were loamy in texture, unsaline, slightly alkaline in pH, moderate in organic matter and lime content and sufficient in available phosphorus and potassium (Table 2).

Table 1. Greenhouse indoor temperature and relative humidity values
Çizelge 1. Sera içi ortalama sıcaklık ve nispi nem değerleri

Months(Aylar)	March(Mart)	April(Nisan)	May(Mayıs)	June(Haziran)	July(Temmuz)
Relative humidity, %	73	67	58	55	50
Temperature, ºC	13.3	15.6	20.6	23.2	24.7

Table 2. Some physical and chemical properties of greenhouse soil
Çizelge 2. Sera toprağı bazı kimyasal ve fiziksel değerler

Depth, cm Derinlik, cm	Texture Bünye	pH	OM, %	Lime, % Kireç, %	EC (dS m^{-1})	Available, kg da^{-1}		
						K_2O	P_2O_5	N
0-30	Loamy	7.79	3.17	7.31	0.85	21.56	42.81	16.25

Om: Organic material, EC: Electrical conductivity

Plant material and method

The F1 hybrid Yağmur pole cucumber cultivar was used as the plant material of the study. Ready-to-plant seedlings with 4-5 true leaves were used in present experiments. The cultivar has a strong structure, medium-long internodes, medium-sized leaves, 2-4 fruits in mid-early node, long fruit stalk (12-14 cm) and strong root structure. Fruits have bright green color, long shelf-life, and good aroma. The cultivar is suitable for winter-early spring greenhouse cultivation. It is a variety with suitable, high yielding, strong root structure. When the seedlings had four true-leaves, they were planted on 25.03.2019 in a 90*50*50 cm double-row planting in the north-south direction with 24 plants in each plot. Along with planting, 10 mm initial water was applied to all treatments at one day intervals, and then irrigation treatments were initiated. The first harvest was performed on 30.04.2019 and the last on 26.07.2019. A total of 31 harvests were made. Cucumbers harvested from each plant were counted and the number of fruits per plant and square meter were determined. Fruits were weighed and yield per plant and decare were calculated.

Experimental treatments included unmulched drip irrigation, drip irrigation+ black polyethylene mulch and drip irrigation+blue polyethylene mulch. Experiments were conducted in randomized blocks design with three replications. In all treatments, two drip lines were placed between two rows (Figure 1).

In drip irrigation+mulch treatments, drip lines were lied over the ground and blue or black polyethylene mulches were placed on top of them. Considering the changes in soil moisture content, irrigation interval was selected as 7 days for drip irrigation + mulch and 4 days for unmulched drip irrigation treatments. Irrigation water is passed through water meters. Irrigation water use efficiency (IWUE) was calculated with the use of Equation 1.

$$IWUE = Y/I \quad (1)$$

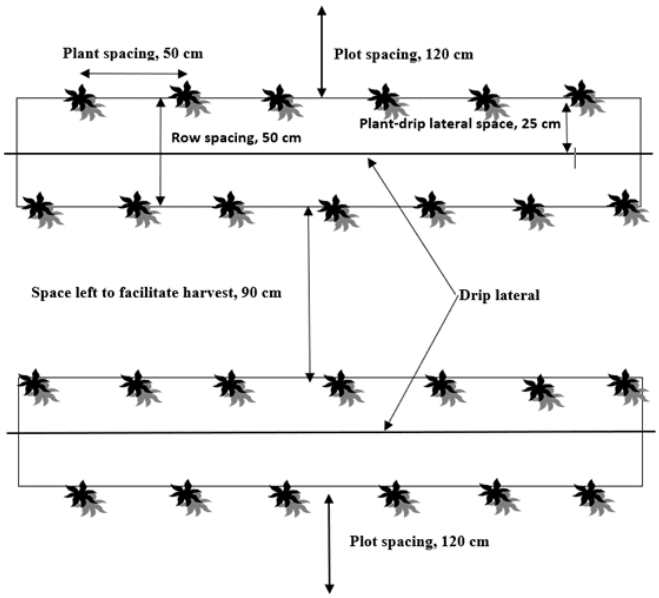

Figure 1. Experimental setup
Şekil 1. Deney düzeni

Where; Y: yield per hectare (kg), I: Amount of irrigation water applied throughout the growing season (mm).

Weed detection as performed from two different parts of each plot with the use of 0.25 m2 (0.5 m X 0.5 m) frames. Following the identification of weed coverage (%) and the number of species, the weeds in the frame were cut from the ground surface and placed into paper bags. Freshly weighed weeds were then dried in an oven at 70 ˚C for 72 hours to get dry biomass (Isik et al., 2009).

Statistical Analysis

Experimental data were subjected to analysis of variance in accordance with randomized blocks design

with the use of SPSS (10.0 for Windows) statistical software. Significant means were compared with the use of LSD test at 0.05 significance level.kale metni. Makale metni. Makale metni. Makale metni. Makale metni. Makale metni. Makale metni. Makale metni. [Century12 regular].

RESULTS AND DISCUSSION

Experimental results were provided in Table 3. The highest yields were obtained from drip irrigation + blue mulch and drip irrigation+black mulch treatments, respectively, and the lowest yields were obtained from unmulched drip irrigation treatments. In terms of yield per decare and per plant, number of fruits per plant and per square meter, significant differences were not seen between blue and black mulch, but there were significant differences between mulching and unmulched treatments.

Table 3. Yield and irrigation water use efficiency of experimental treatments (mean ± SE)
Çizelge 3. Uygulamalardaki verim ve su kullanım etkinliği değerleri (ortalama ± SE)

Treatments Uygulamalar	Yield per plant, kg Bitki başına verim, kg	Yield per unit area, kg m^{-2} Metrekareye verim, kg m^{-2}	Yield per decare, kg da^{-1} Dekara verim, Kg da^{-1}	Number of fruits per plant Bitki başına meyve sayısı	Number of fruits per unit area, fruit m^{-2} Metrekareye meyve sayısı	IWUE (kg $ha^{-1}mm^{-1}$)
Drip+blue mulch Damla+mavi malç	4.28[a*] (±0.45)	12.22[a] (±1.30)	12297[a] (±1300.3)	46.00[a] (±3.65)	131.42[a] (±13.31)	187.73
Drip+black mulch Damla+siyah malç	4.12[a] (±0.39)	11.78[a] (±1.12)	11784[a] (±1124.8)	45.16[a] (±1.811)	129.02[a] (±5.17)	179.90
Unmulched drip Malçsız damla	2.72[b] (±0.38)	7.77[b] (±1.09)	7771[b] (±1094.3)	31.33[b] (±4.12)	89.51[b] (±11.79)	100.14

*: significant at 0.05 level

Throughout the growing season, 16 irrigations were practiced in drip irrigation+mulch treatments and subjects and 29 irrigations were practiced in unmulched drip irrigation treatments. Again, throughout the growing season, 655 mm water was applied in drip irrigation+mulch treatments and 776 mm water was applied in unmulched drip irrigation treatments. The highest yield per decare (12296.7 kg) was obtained from drip irrigation+blue mulch treatments and the lowest yield (7771.0 kg) was obtained from unmulched drip irrigation treatments. The difference is 4525.7 kg, and 37% more yield was obtained from drip irrigation+blue mulch treatments. As compared to unmulched drip irrigation treatments, 34% more yield was obtained from drip irrigation+black mulch treatments. Similar findings were obtained for the other yield components (Table 3).

Irrigation water use efficiency (IWUE) indicates the amount of yield obtained per unit of irrigation water. Higher values indicate more efficient use of irrigation water and greater yield levels. The highest irrigation water usage efficiency values were obtained from drip irrigation+blue mulch treatments and the least from unmulched drip irrigation treatments. Present findings revealed that drip irrigation + mulch treatments were more effective in terms of yield and irrigation water use efficiency as compared to unmulched drip irrigation treatments in cucumber cultivation in greenhouses. It was indicated in a study (Díaz-Pérez and Batal., 2002) that yield, and water use efficiency of cucumber grown in field conditions was higher in drip irrigation+black mulch treatments than in unmulched drip irrigation treatments and yield increase was attributed to mulching treatments. In another study comparing unmulched drip irrigation and drip irrigation+mulch (black and transparent) treatments, the highest yield was obtained from drip irrigation+black mulch treatments (Spiżewski et al., 2010). Similarly, Yaghi et al. (2013) investigated the effects of different mulches on cucumber yield and obtained the greatest yield from black plastic mulch treatments. In a study carried out on eggplant under greenhouse conditions, the highest yield values (115 and 107 t ha-1) were respectively obtained from black and blue mulch treatments (Gerçek and Demirkaya, 2020). In another study investigating the effect of black and blue mulches on two different pepper varieties under greenhouse conditions, the highest yields were obtained from blue mulching treatments and there was no significant difference between blue and black mulches (Gerçek and Demirkaya, 2021). Present findings comply with those earlier ones. In general, it can be concluded that use of mulch together with drip irrigation was a measure to increase the yield of cucumbers. In addition, since black mulches prevent weeds and increase soil temperature, it can easily be used in cucumber cultivation.

Weed species encountered in experimental plots and weed densities are given in Table 4.

Table 4. Weeds encountered and densities
Çizelge 4. Yabancı otlar ve yoğunlukları

Weeds Yabancı otlar	*Density, crop m^{-2}* *Yoğunluk, bitki m^{-2}*	
	04.07.2019	23.08.2019
Portulaca oleracea L.	16.8	4.2
Poa annua L.	12.4	5.2
Tribulus terrestris L.	7.2	3.4
Digitaria sanguinalis (L.) Scop.	6.5	4.4
Amaranthus retroflexus L.	6.0	3.4
Chenopodium album L.	5.2	2.1
Polygonum aviculare L.	3.6	0.8
Seteria viridis (L.) P.Beauv	3.4	4.2
Atriplex patula L.	3.4	-
Convolvulus arvensis L.	2.6	0.3
Heliotropium europaeum L.	1.0	0.8
Solanum nigrum L.	0.8	0.6
Stellaria media (L.) Vill.	0.4	-
Lactuca serriola L.	0.3	-
Crepis macropus Boiss.	0.2	-
Toplam	69.8	29.4

The most common weed species encountered in the experimental plots were Portulaca oleracea L., Poa annua L. Tribulus terrestris L., Digitaria sanguinalis (L.) Scop. Amaranthus retroflexus L. and Chenopodium album L. All these weeds are also common in the other summer crops of the region (Özdemir and Işık 2000; Mennan et al. 2009). Especially weeds such as P. oleracea, A. retroflexus, C. album and Seteria spp were reported in previous studies on different crops cultivated in Turkey (Özdemir and Işık 2000; Mennan et al. 2009; Akça and Işık 2016).

Weed fresh and dry weights and cover ratios of experimental treatments are provided Table 5. Weed population and biomass were significantly affected by the experimental treatments. As seen in Table 5, weeds formed biomass only in unmulched drip irrigation plots. In drip irrigation+mulch treatments, quite a small amount of weed growth was seen from holes around seedling bottoms. In terms of weed biomass, there was no significant difference between black and blue mulches ($p<0.05$). Mulching prevents weed growth by both blocking light intrusion and creating a physical barrier (Jabran, 2019). Previous researchers also pointed out weed growth-inhibition effect of plastic mulches (Teasdale and Mohler 2000; Ramakrishna 2006; Rajablariani et al. 2012).

Table 5. Effects of experimental treatments on weed biomass and cover ratios (mean ± SE)
Çizelge 5. Uygulamalardaki yabancı ot ağırlıkları ve alanı kaplama oranları (ortalama ± SE)

Treatments Uygulamalar	Weed fresh weight, g m^{-2} Yabancı ot yaş ağırlığı, g m^{-2}	Weed dry weight, g m^{-2} Yabancı ot kuru ağırlığı, g m^{-2}	Cover Ratio, % Kaplama oranı, %
Unmulched drip Malçsız damla	842.54^{a*} (±20.11)	88.42^{a} (±2.69)	95
Drip+black mulch Damla+siyah malç	52.59^{b} (±6.40)	5.08^{b} (±0.13)	< 1
Drip+blue mulch Damla+mavi malç	43.04^{b} (±1.87)	3.04^{b} (±0.19)	< 1

*: significant at 0.05 level.

CONCLUSION

It was concluded based on present findings that in cucumber cultivation under greenhouse conditions, mulching treatments applied together with drip irrigation significantly prevented weed growth, thus offered significant savings of resources and labour for weed control; increased irrigation water use efficiency thus offered greater quantity of production. Therefore, blue, and black mulches could reliably be recommended for greenhouse cucumber cultivation. On the other hand, measures to be taken to increase yields in open fields are highly limited because of unexpected instantaneous changes in climate parameters frequently encountered in open fields.

However, climate and plant growth parameters are continuously monitored and controlled in greenhouse, such negative effects of instant changes are not encountered in greenhouses. Mulching treatments are recommended also for high irrigation water use efficiencies.

Author's Contributions

The contribution of the authors is equal.

Statement of Conflict of Interest

Authors have declared no conflict of interest.

REFERENCES

Akça A, Işık D 2016. Kayseri İli şeker pancarı (Beta vulgaris L.) ekiliş alanlarında bulunan yabancı otların tespiti. Bitki Koruma Bülteni 56 (1):115-124.

Anonymous 2021a. Food and Agriculture Organization of the United Nations Faostat. http://www.fao.org/faostat/en/#data/QCL. (Erişim Tarihi:12.08.2021).

Anonymous 2021b. T.C. Tarım ve Orman Bakanlığı Bitkisel Üretim Verileri. https://www.tarimorman.gov.tr/sgb/Belgeler/SagMenuVeriler/BUGEM.pdf (Erişim Tarihi: 12.08.2021).

Csizinky AA, Schuster DJ, Kring JB 1995. Color mulches influence yield and insect pest populations in tomatoes. Journal of the American Society for Horticultural Science 120(5):778-784.

Haapala T, Palonen P, Tamminen A, Ahokas J 2015. Effects of different paper mulches on soil temperature and yield of cucumber (Cucumis sativus L.) in the temperate zone. Agricultural and Food Science 24(1):52-58.

Delibaş L 1994. Sulama. Trakya Üniversitesi Tekirdağ Ziraat Fakültesi Basımevi, Tekirdağ, 199 sy.

Díaz-Pérez JC, Batal, KD 2002. Colored plastic film mulches affect tomato growth and yield via changes in root-zone temperature. Journal of the American Society for Horticultural Science 127(1):127-136.

Gerçek S, Demirkaya M 2020. Effects of colored water pillows on yield and water productivity of eggplant. Irrigation and Drainage 69:658-667.

Gerçek S, Demirkaya M 2021. Impact of colored water pillows on yield and water productivity of pepper under greenhouse conditions. Agricultural Water Management 250:1-7.

Gerçek S, Demirkaya M, Isik D 2017. Water pillow irrigation versus drip irrigation with regard to growth and yield of tomato grown under greenhouse conditions in a semi-arid region. Agricultural Water Management 180:172-177.

Isik D, Kaya E, Ngouajio M, Mennan H 2009. Weed suppression in organic pepper (Capsicum annuum L.) with winter cover crops. Crop Protection, 24, 356–363.

Jabran K 2019. Mulches for weed control in role of mulching in pest management and agricultural sustainability. Springer Briefs in Plant Science. Springer, Cham. https://doi.org/10.1007/978-3-030-22301-4_2

Mennan H, Ngouajio M, Kaya E, Isık D 2009. Weed management in organically grown kale (Brassica oleracea var: acephala) using alternative cover cropping systems. Weed Technology 23:81-88.

Özdemir Ç, Işık D 2020. Kayseri İli çerezlik kabak ekiliş alanlarında görülen yabancı otların tespiti. Türkiye Herboloji Dergisi 23(1):74-80.

Ramakrishna A, Tam HM, Wani SP, Long TD 2006. Effects of mulch on soil temperature, moisture, weed infestation and yield of groundnut in northern Vietnam. Field Crop Research, 95:115-125.

Rajablariani HR, Hassankhan F, Rafezi R 2012. Effect of colored plastic mulches on yield of tomato and weed biomass. Int. J. of Environmental Science and Development 3 (6):590-593.

Spiżewski T, Frąszczak B, Kałużewicz A, Krzesinski W, Lisiecka J 2010. The effect of black polyethylene mulch on yield of field-grown cucumber. Acta scientiarum Polonorum. Hortorum Cultus 9:221-229.

Şalk A, Arın L, Deveci M, Polat S 2008. Özel Sebzecilik. Sevil Cilt Evi ve Matbaası, Tekirdağ, S. 379.

Tarara JM 2000. Microclimate modification with plastic mulch. HortScience 35:169-180.

Teasdale JR, Mohler CL 2000. The quantitative relationship between weed emergence and the physical proprieties of mulches. Weed Sciences 48:385-392.

Torres-Olivar V, Ibarra-Jiménez L, Cárdenas-Flores A, Hugo Lira-Saldivar R, Humberto Valenzuela-Soto J, Castillo-Campohermoso MA 2018. Changes induced by plastic film mulches on soil temperature and their relevance in growth and fruit yield of pickling cucumber. Acta Agriculturae Scandinavica, Section B-Soil & Plant Science 68(2): 97-103.

Yaghi T, Arslan A, Naoum F 2013. Cucumber (Cucumis sativus, L.) water use efficiency (WUE) under plastic mulch and drip irrigation. Agricultural Water Management 128:149-157.