

The effect of different mulch materials with varying thicknesses on weed control and yield in eggplant cultivation

Ramazan Gurbuz^{1,*}, Serkan Çağlar¹, Harun Alptekin¹, Volkan Okatan²,
İbrahim Kahramanoğlu³

¹ Department of Plant Protection, Faculty of Agriculture, Iğdır University, Iğdır 76000, Turkey

² Department of Horticulture, Faculty of Agriculture, Eskişehir Osmangazi University, Eskişehir 26040, Turkey

³ Department of Horticulture, Faculty of Agricultural Sciences and Technologies, European University of Lefke, Gemikonağı 99870 Turkey

ABSTRACT

Weeds are a significant problem in eggplant (*Solanum melongena* L.) cultivation, causing high yield losses and negatively affecting plant growth. This study aimed to assess the effects of different mulching materials and thicknesses on weed control and plant yield in eggplant cultivation. Three mulching materials [wheat straw (WS), grass clippings (CTG) and shredded paper (CP)] were applied at three thicknesses (5 cm, 10 cm and 15 cm). Parameters, such as weed density, dry weight and eggplant yield, were assessed during and after eggplant cultivation. Mulching was effective in reducing weed density and dry weight, with 15 cm CTG being the most effective. The most effective weed control was achieved using the CTG-15 mulching material. While *Sorghum halepense* L. maintained high densities even <15 cm thick mulches, *Xanthium strumarium* L., *Convolvulus arvensis* L. and other species were effectively controlled with mulch thicknesses of ≥5 cm. Additionally, significant increases in eggplant yield were observed with mulching applications. The application of CTG resulted in the highest yield (15 cm: 83.20 t · ha⁻¹) of all mulch types, with an average yield that was 75% higher than the control plot. A negative relationship was found between weed density and dry weight and eggplant yield. These findings emphasise the practical value of selecting the right mulch material and thickness to enhance yield and suppress weeds effectively.

Keywords: grass, mulching, paper, *Solanum melongena* L., straw, weed

Abbreviations: CP, shredded paper; CTG, grass clippings; FAO, Food and Agriculture Organization; MS, meteorological service; TUIK, Turkish Statistical Institute; WS, wheat straw.

INTRODUCTION

Eggplant (*Solanum melongena* L.) is an important vegetable in the Solanaceae family, commonly cultivated in tropical and temperate regions worldwide (Kasirajan and Ngouajio, 2012; Taher et al., 2017). It is of significant nutritional value, containing around 24 calories per 100 g, as well as protein, fat, carbohydrates and vitamins A, B₁, B₂ and C (Akkuş, 2015). Additionally, it is used

for medicinal purposes, such as treating diabetes, asthma, bronchitis and diarrhoea, and it stimulates the metabolism of blood cholesterol (Braga et al., 2016). It plays a crucial role in human nutrition. The global eggplant production reached around 59.3 million tonnes in 2022, with the highest production in Asia (94.21%), followed by Africa (3.68%) and Europe (1.7%). The

*Corresponding author.

e-mail: r_grbz@yahoo.com (Ramazan Gurbuz).

leading eggplant-producing countries in 2022 were China (32.28 Mt), India (12.76 Mt), Egypt (1.39 Mt) and Turkey (0.8 Mt) (FAO, 2024). In 2023, Turkey cultivated eggplant on 166751 decares of land, which yielded 781242 tonnes (TUIK, 2024).

The rapidly growing world population increases the demand for agricultural products. To meet this demand, global agricultural production must double by 2050 (Ray et al., 2013). Increasing plant production is crucial to addressing nutritional needs (Foley et al., 2011). Instead of expanding agricultural land, the priority should be on increasing crop yields through sustainable methods (Hulme et al., 2013; Ray et al., 2013; Gerten et al., 2020). Eggplant is an important crop worldwide and especially in Turkey, but several factors contribute to yield and quality losses. Weeds, in particular, hinder eggplant growth, adversely affecting yield and quality of fruit (Abdrabbo et al., 2017; Marques et al., 2019; Zargar et al., 2022). Research has shown that weeds can cause yield losses of up to 78% in eggplant (Marques et al., 2017), with loss rates varying between 67% and 96% (Aramendiz-Tatis et al., 2010). Weeds also significantly reduce dry matter and macro-nutrient accumulation in eggplant (Marques et al., 2019). Weed control is a key component of sustainable agriculture. Weeds, especially perennials, can tolerate several environmental stress conditions (Ihtisham et al., 2023) much more than the cultivated crops, and cause high yield losses. In high-value vegetables like eggplant, reducing weed pressure is crucial for preventing yield and quality losses. The intensity and duration of weed control methods are critical factors that can determine the extent of yield loss (Swanton et al., 2015). Herbicides are commonly used in eggplant cultivation due to their rapid action, ease of application and low cost (Kitiş, 2020); however, their improper and excessive use can negatively impact human health (Jabłońska-Trypuć et al., 2019) and cause severe environmental issues (Sardana et al., 2017). This highlights the need for more sustainable agricultural techniques with minimal environmental impact (Godfray et al., 2010; Lopes et al., 2011). Plastic film mulches are commonly used in eggplant production (Sabatino et al., 2018; Díaz-Pérez, 2023). Mulching offers significant soil health benefits over chemical herbicides by increasing soil microbial activity, improving structure and retaining moisture. Organic mulches, such as straw or wood chips, decompose over time, enriching the soil with organic matter and promoting microbial diversity. By contrast, some herbicides can disrupt soil microbial populations, reducing fertility (Omidvar et al., 2023). In addition, mulching prevents soil compaction and increases water infiltration, whereas chemical herbicides can lead to soil degradation over time (Iqbal et al., 2020). Mulch also suppresses weed growth by creating a physical barrier and prevents non-target organisms from being harmed without creating chemical residues (Neal et al., 2015). These comprehensive benefits make mulching a more sustainable and environmentally friendly alternative to chemical weed management methods.

Polyethylene mulches, in particular, play a crucial role in crop production (Di Miceli et al., 2024). However, the disposal or recycling of contaminated mulches presents environmental concerns (Steinmetz et al., 2016; Di Miceli et al., 2024), and their recycling can be challenging (Tarara, 2000).

Mulching of non-synthetic origin is an effective method for combating the negative effects of chemical control and addressing weed issues. This method involves applying various organic and biodegradable materials to the soil surface to reduce weed populations, prevent moisture loss and enhance crop yield (Forcella et al., 2003; Gilreath and Santos, 2005; Yu et al., 2018). Mulches function as a barrier by blocking light and physically suppressing weed emergence (Ahmad et al., 2020; Iqbal et al., 2020). Mulching plays a significant role in the production of such vegetables (Alptekin and Gürbüz, 2022; Tülek et al., 2022; Usanmaz Bozhüyük et al., 2022; Gürbüz et al., 2024). It is commonly used in eggplant production (Gürbüz et al., 2021; Di Miceli et al., 2024; Nyasapoh et al., 2024), and it increases the yield significantly (Al-Bayati and Hamdoon, 2019; Gürbüz et al., 2021). Based on the previous discussion, there is a need for new, environmentally friendly agricultural practices for sustainable food production (Iqbal et al., 2020). Organic mulches offer an effective solution for sustainable agriculture by conserving soil moisture and nutrients, suppressing weeds and enhancing crop yield (Nyasapoh et al., 2024). However, factors such as mulch thickness, application timing, replacement frequency (Gómez De Barreda et al., 2023) and selection of mulch material should be based on soil type, environmental conditions and the targeted production goal (Jabran, 2019). Typically, mulches are applied in a 5–10 cm thick layer (Syed Shahnaz, 2023). However, research has shown that low amounts of mulch are insufficient for controlling weeds and increasing yield (Döring et al., 2005). Therefore, determining the ideal thickness is crucial for both material conservation and maximum effectiveness. This study aims to fill these gaps by evaluating the effectiveness of different organic mulches [wheat straw (WS), grass clippings (CTG) and shredded paper (CP)] applied in different thicknesses (5 cm, 10 cm and 15 cm) to control weed populations and increase eggplant yields. This approach promotes soil health and reduces the environmental risks associated with synthetic materials, while providing a sustainable alternative to plastic mulches. The results of this study are expected to contribute to the development of sustainable agricultural practices by providing practical recommendations for the selection of mulch materials and application thicknesses that optimise weed suppression and crop yield.

MATERIALS AND METHODS

This study was conducted in 2021 and 2022 at the Iğdır University Agricultural Practice and Research Center (39°55'45.6" N, 44°05'42.3" E). The 'Pulsar' F₁ eggplant cultivar (Graines Voltz Turkey Tohumculuk®, Turkey)

was used in the experiment. The meteorological data for Iğdır Province during the study months in 2021 and 2022, along with the long-term average (LTA) from 1941 to 2022, are presented in Table 1.

Soil samples representing the experimental field were collected from a depth of 0–30 cm before planting for soil analysis. The soil texture class of the experimental field is clay loam, with a lime (CaCO_3) content of 11.32%, total salt of $2 \text{ mmhos} \cdot \text{cm}^{-1}$, pH value of 7.9, available phosphorus (P_2O_5) value of $0.8 \text{ kg} \cdot \text{da}^{-1}$, available potassium (K_2O) value of $9.28 \text{ kg} \cdot \text{da}^{-1}$ and organic matter content of 1.8%. This study utilised WS ('Demir 2000' variety) obtained from the Central Research Institute for Field Crops (CRIFC) in Ankara, Turkey; cut grass waste [a mixture of *Festuca arundinacea* L. (45%), *Lolium perenne* L. (25%), *Festuca rubra* subsp. *rubra* (20%) and *Poa pratensis* L. (10%)] and shredded writing paper materials (Table 2).

Three types of organic mulching materials were selected: WS, CTG and CP. These materials were chosen due to their local availability, cost-effectiveness and ease of application. Additionally, WS is known for its slow decomposition rate and ability to suppress weeds effectively, CTG provide quick decomposition and nutrient enrichment, and CP acts as an effective barrier

against light penetration, reducing weed emergence. The mulches were applied at three different thickness levels: 5 cm, 10 cm and 15 cm. These thickness levels were based on previous studies suggesting optimal weed suppression and soil moisture retention (Greenly and Rakow, 1995; Van Donk et al., 2012). These findings support the application of mulch at thicknesses between 5 cm and 15 cm to optimise both weed control and soil moisture retention.

Eggplant planting, maintenance and experimental set-up

The research was conducted at the Agricultural Application and Research Center of Iğdır University. In the first year, eggplant seedlings were planted on 7 May 2021, and in the second year on 29 April 2022, with row spacing of 70 cm and plant spacing of 50 cm. The seedlings were planted in tilled soil with two-thirds of the seedling's height below the soil and one-third above the soil. Before planting, $45 \text{ kg} \cdot \text{da}^{-1}$ of NPK fertiliser (Toros Classical Fertilizers) was mixed into the soil. After planting, a drip irrigation system with drippers spaced 20 cm apart was installed, and the first irrigation was carried out immediately. The system utilised drippers with a flow rate of $2 \text{ L} \cdot \text{hr}^{-1}$

Table 1. Meteorological data for Iğdır province between 2021 and 2022 and LTA (1941–2020).

Months	Average temperature ($^{\circ}\text{C}$)			Total precipitation (mm)			Average relative humidity (%)		
	2021	2022	LTA	2021	2022	LTA	2021	2022	LTA
March	10.0	10.4	6.2	17.5	18.1	22.1	60.5	65.6	52.2
April	17.4	11.5	13.0	18.4	83.6	33.8	43.6	76.6	49.9
May	21.1	18.8	17.7	42.1	76.1	46.5	46.3	63.1	51.5
June	26.8	24.2	22.1	0.7	15.7	32.0	33.9	48.3	47.3
July	27.4	26.7	25.9	32.4	30.2	13.7	45.7	48.4	45.3
August	27.4	24.2	25.3	8.3	15.3	9.7	40.6	47.6	47.1
September	22.2	23.5	20.4	11.5	1.4	11.5	44.8	47.7	46.2
October	12.7	14.5	13.1	18.5	7.3	26.3	60.0	49.6	48.5

Meteorological Service of Türkiye; LTA, long-term average (MS, 2024).

Table 2. General properties and application rates of mulch materials used in the study.

Code	Material used	General characteristics	Application quantities
CP-5	CP 5 cm	Paper pieces cut vertically into 1 cm pieces	$1000 \text{ kg} \cdot \text{da}^{-1}$
CP-10	CP 10 cm		$2000 \text{ kg} \cdot \text{da}^{-1}$
CP-15	CP 15 cm		$3000 \text{ kg} \cdot \text{da}^{-1}$
CTG-5 cm	CTG 5 cm	Mixed CTG: <i>L. perenne</i> 25%, <i>F. arundinacea</i> 45%, <i>P. pratensis</i> 10%, <i>F. rubra</i> subsp. <i>rubra</i> 20%	$1750 \text{ kg} \cdot \text{da}^{-1}$
CTG-10 cm	CTG 10 cm		$3500 \text{ kg} \cdot \text{da}^{-1}$
CTG-15 cm	CTG 15 cm		$5250 \text{ kg} \cdot \text{da}^{-1}$
WS-5	WS 5 cm	WS ('Demir 2000' variety)	$1500 \text{ kg} \cdot \text{da}^{-1}$
WS-10	WS 10 cm		$3000 \text{ kg} \cdot \text{da}^{-1}$
WS-15	WS 15 cm		$4500 \text{ kg} \cdot \text{da}^{-1}$

CP, shredded paper; CTG, grass clippings; WS, wheat straw.

to ensure efficient water distribution. Subsequent irrigations were performed weekly, with the duration adjusted based on rainfall, soil moisture levels and the plant's water requirements. Given the 20 cm dripper spacing, each irrigation session lasted for approximately 1–2 hr, depending on the environmental conditions and soil absorption capacity. This study was designed using a randomised block design with 11 treatments (3 mulch materials: CP, WS and mowed grass, and 3 different mulch thicknesses: 5 cm, 10 cm and 15 cm, with or without weeds), replicated 4 times, resulting in a total of 44 plots. Plotting was done after the eggplant planting and before applying the mulch materials. The experimental layout was designed with plots measuring 4.0 m × 1.5 m, where 16 seedlings were planted in each 6 m² plot. A 0.5 m strip of bare soil was left between the plots and blocks. The total experimental area covered 376.25 m². For plot division, stakes were fixed to the ground, and strings were used within the strips. Mulch materials were applied on 25 June 2021 in the first year and on 10 June 2022 in the second year. Care was taken to ensure that the eggplant seedlings were not covered by mulch. In the weed-free plots, weeding by hoeing and manual removal was carried out according to the weed emergence status.

Determination of weed species and density in the experimental area

To identify the weed species and their densities in the experimental area, a 1 m² wooden frame was randomly placed, and the weeds within the frame were counted. The weed density was determined based on the arithmetic mean. The weed density (plants · m⁻²) was calculated by dividing the total number of plants counted in the survey by the number of surveys conducted, with the density of each species determined individually (Odum, 1971):

$$\text{Density (plants} \times \text{m}^{-2}) = \frac{B}{M}$$

B is the total density of each species in the surveyed areas (number of plants), and M is the total surveyed area (m²).

Additionally, the weed densities of the species found in the experimental area were rated using the density scale (Table 3) proposed by Üstüner and Güncan (2002).

Weed emergence and weed species

After mulching materials were applied in both years, weed emergence was determined by counting the weed density in m² once a month. A total of three counts were made during the study. The weed density was counted for both the total density in the plots and the species-specific density. For the plots with mulching materials, only the emerged weeds were counted, and these were recorded separately for each species. After evaluating the species, the total weed density in m² was determined for each plot. In plots with mulching materials, the weed

Table 3. Density scale of weeds.

Classification	Density level	Density (plants · m ⁻²)
A	High density	>10
B	Dense	1–10
C	Medium density	0.1–1
D	Low density	0.01–0.1
E	Rare	<0.01

species *Sorghum halepense*, *Convolvulus arvensis* and *Xanthium strumarium* were evaluated separately due to their homogeneous emergence. Other weeds that did not show a homogeneous emergence were evaluated as a whole.

To determine the total weed density for all treatments, 1 m² frames were used for sampling. The density values for each count date were calculated using the formula proposed by Odum (1971), as mentioned earlier. According to this method, the total number of weeds was divided by the total surveyed area to determine the density for each treatment.

Weed dry weight

In both years of the study, before the final harvest, the weeds present in all plots were cut at the soil surface, placed in paper bags and transported to the Herbolology Laboratory. In the laboratory, the samples were dried in an oven at 70°C for 72 hr and then weighed to determine their dry weight accurately. These data were recorded, and the dry weight of weeds per m² was calculated. Additionally, the percentage effect on weed dry weight compared with the weed-infested control plots was determined.

Eggplant yield components and yield

The eggplant harvest was carried out between 23 July and 12 October 2021 in the first year and between 28 July and 5 October 2022 in the second year. Several parameters were measured to assess the yield components and the total yield, including plant height (cm), number of fruits per plant (count), fruit weight (g), yield per plant (kg) and total yield (t · ha⁻¹). Plant height was measured from the base of the plant to the final point of growth using a tape measure or ruler for accuracy. Fruit weight was determined using a digital precision scale (±0.01 g accuracy) to ensure accurate measurements. Yield per plant and total yield were calculated from the total number of fruits harvested and their recorded weights, providing a comprehensive assessment of productivity. Yield and yield components were compared for mulched plots against weed-infested control and weed-free control plots (using hoeing and manual weeding).

Data analysis

The weed densities, weed dry weights, and eggplant yield and yield components were evaluated based on three

different counts made during the study. The relevant data were subjected to one-way analysis of variance (ANOVA). Means were compared using the Duncan multiple range test ($p < 0.05$). Statistical analysis was performed using SPSS 20 (IBM, 2011). Additionally, a series of statistical analyses were performed to relate the findings of the study. After data transformation/normalisation, correlation analysis was performed using JASP (version 0.16.4.0, December 2020) to determine the degree of relationship between the variables and to identify the strong and weak correlations. Heatmap clustering (SRplot) was performed to visualise data density and identify similar groups. Hierarchical clustering (SRplot) was used to group the treatments based on similarities. Network analysis (PAST Software, 2023) was conducted to determine and visualise the relationships between variables. Principal Component Analysis (PAST Software) was also applied to reduce multivariate data to fewer dimensions and identify the significant variables.

RESULTS AND DISCUSSION

Weed species and density identified in the experimental area

A total of 17 weed species from 8 families were identified. The families, scientific names, common names and life cycles of the weed species found in the experimental area are given in Table 4.

According to the study results, *S. halepense* was the most abundant species in both years (14.5 plants · m⁻² in 2021 and 10.6 plants · m⁻² in 2022). When compared with the literature, species such as *C. arvensis*, *Chenopodium album*, *Portulaca oleracea* and *S. halepense* were commonly identified in both this study and prior research conducted by Tepe (2022), Gürbüz et al. (2021) and Kaya (2011). Similarly, *Cynodon dactylon* and *Solanum nigrum*, identified in studies by Aliyu and Lagoke (1995) and Altinok (2013), were consistent with the findings of this research. Marques et al. (2017) also reported major weed species such as *Eleusine*

Table 4. Weed families, scientific names, common names and life cycles of the identified weed species in the experimental area.

Family	Scientific name	Common name	Life cycle	Density (plants · m ⁻²) – Density scale		
				2021	2022	Mean
Narrow-leaved						
Poaceae	<i>Sorghum halepense</i> (L.) Pers.	Johnson grass	P	14.5 A	10.6 A	12.6 A
	<i>Seteria verticillata</i> (L.) P.B.	Bristly foxtail	A	0.8 C	0.6 C	0.7 C
	<i>Cynodon dactylon</i> (L.) Pers.	Bermuda grass	P	0.5 C	0.1 C	0.3 C
Broad-leaved						
Amaranthaceae	<i>Amaranthus retroflexus</i> L.	Redroot pigweed	A	-	0.2 C	0.1 C
	<i>Chenopodium album</i> L.	Common lambsquarters	A	5.5 B	6.0 B	5.8 B
	<i>Atriplex nitens</i> Schkuhr.	Mountain spinach	P	0.6 C	0.6 C	0.6 C
Asteraceae	<i>Suaeda altissima</i> (L.) PALL	Sea blight	A	0.2 C	0.3 C	0.3 C
	<i>Cirsium arvense</i> (L.) Scop.	Canada thistle	P	0.9 C	0.8 C	0.8 C
	<i>Xanthium strumarium</i> L.	Common cocklebur	A	4.8 B	5.0 B	4.9 B
Brassicaceae	<i>Sinapis arvensis</i> L.	mustard	A	0.3 C	-	0.2 C
	<i>Descurainia sophia</i> (L.) Webb. Ex Prant.	Flixweed	A	0.2 C	-	0.1 C
	<i>Cardaria draba</i> (L.) Desv.	Hoary cress	P	0.4 C	0.5 C	0.5 C
Convolvulaceae	<i>Myagrum perfoliatum</i> L.	Field mustard	A	0.8 C	0.4 C	0.6 C
	<i>Convolvulus arvensis</i> L.	Field bindweed	P	4.3 B	3.8 B	4.0 B
	Fabaceae	<i>Alhagi pseudalhagi</i> (BIEB.) DESV.	Camelthorn	P	0.5 C	-
Portulacaceae		<i>Portulaca oleracea</i> L.	Purslane	A	0.5 C	0.6 C
	<i>Polygonum aviculare</i> L.	Prostrate knotweed	A	0.3 C	0.3 C	0.3 C
Parasitic						
Cuscutaceae	<i>Cuscuta</i> spp.	Dodder	Parasitic	0.3 C	0.1 C	0.2 C

Life cycle: A – annual; P – perennial.

Density scale: A – high density, ≥10.00 plants · m⁻²; B – intensive, 1.00–10.00 plants · m⁻²; C – medium, 0.10–1.00 plants · m⁻².

indica, *Portulaca oleracea* and *Cyperus rotundus* in the experimental areas. In summary, the diversity and prevalence of weed species identified in the eggplant planting area align with findings from previous studies, highlighting the widespread nature of these species in agricultural fields.

Effect of mulching on weed population and species

The three periodic counts showed a significant difference in the density of the weeds. These differences varied depending on the mulching material used. Statistical analysis showed that the effects of different mulching materials on weed density in eggplant fields were significant at the 1% level ($p < 0.01$) for both years and all counts. The average values of weed density and the groupings formed are presented in Figure 1. These results underscore the effectiveness of mulching in reducing weed populations and its potential to influence specific weed species.

In the evaluations of both years, statistically significant differences were observed among applications in terms of weed density. Although weed densities increased during the evaluation periods, all mulch applications achieved lower density values compared with the weedy control group. In both years, the lowest weed density in the final evaluation was achieved with the CTG-15 mulch material (3.37 plants $\cdot$ m $^{-2}$ in 2021 and 3 plants $\cdot$ m $^{-2}$ in 2022). The highest weed density was observed in the weedy control plots, with values of 67 plants $\cdot$ m $^{-2}$ in 2021 and 75.5 plants $\cdot$ m $^{-2}$ in 2022. Overall, it was seen that mulch materials successfully controlled weeds compared with the control plots and that weed density further decreased as mulch thickness increased. These findings support previous studies such as those of Kaya (2011) and Jodaugiene et al. (2006). Kaya (2011), in a study where different plants were

used as mulch material, indicated that mulching reduced weed density. Jodaugiene et al. (2006) expressed that increasing mulch thickness enhanced weed control, especially by preventing the emergence of annual weeds. Additionally, Ahmed et al. (2016) and El-Semellawy and El-Koumy (2015) emphasised that mulching suppresses weeds similarly. These results demonstrate that mulch material and thickness are important factors in weed control and that mulching is particularly effective in controlling annual weeds. Furthermore, Gradila et al. (2023) stated that mulching effectively controlled weeds, which is consistent with our study.

In this study, it was seen that the effects of the mulch materials on weed species varied. Specifically, *S. halepense*, *C. arvensis* and *X. strumarium* were prioritised because they were homogeneous and prevalent across the mulch materials. Additionally, other weed species were observed in the plots with mulch materials, but when their emergence was not homogeneous, they were evaluated as a whole in terms of the weed species present in the experimental area (Figure 1). The effect of mulching on *S. halepense* is given in Table 5, on *C. arvensis* in Table 6, on *X. strumarium* in Table 7 and on other weeds in Table 8.

Evaluations conducted on the weed species in the trial area revealed that the effects of different mulching applications and mulch thicknesses varied across weed species. Particularly, the *S. halepense* species, which was observed at high densities, persisted under mulch materials applied at a thickness of 5 cm and was able to maintain its high density even under some 10 cm mulch applications. *S. halepense*, compared with other weed species, was less affected by the protective impact of the mulch and continued to grow despite the presence of thick mulch layers. By contrast, observations of other dominant species, such as *X. strumarium* and *C. arvensis*, indicated that mulch thickness had a more

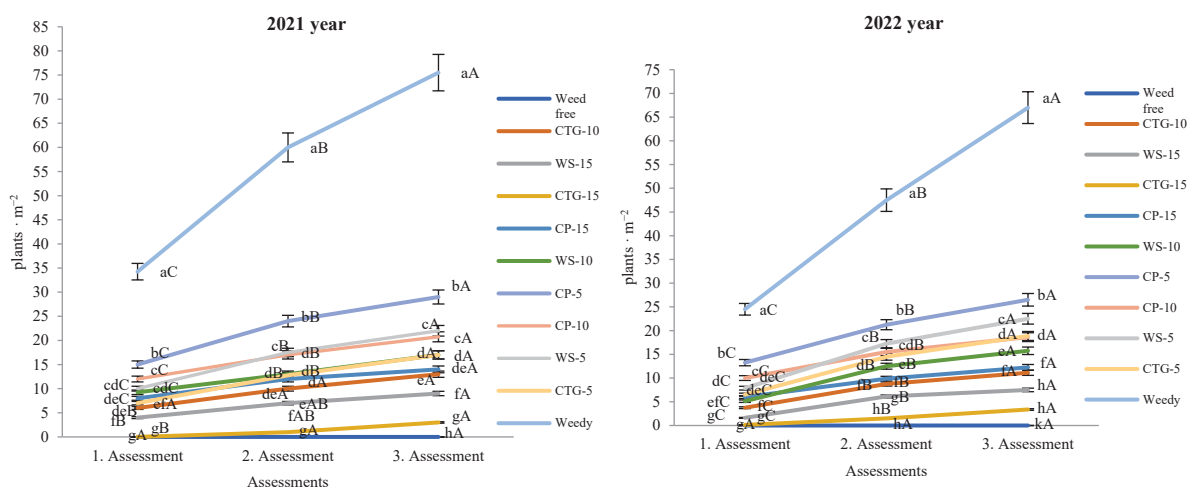


Figure 1. Effect of mulching on weed population (CP, CTG and WS). Lowercase letters indicate groupings among the treatments, while uppercase letters indicate groupings among evaluations within each treatment. Differences between means indicated by the same letter are not significant at the 0.05 level. CP, shredded paper; CTG, grass clippings; WS, wheat straw.

Table 5. Effect of mulching on *S. halepense*.

SORG	2021 year					2022 year					Mean			
	1. E	2. E	3. E	F	p	1. E	2. E	3. E	F	p	1. E	2. E	3. E	F
TRE														
Weed free	0.00 f	0.00 g	0.00 h	-	-	0.00 d	0.00 g	0.00 h	-	-	0.00 e	0.00 g	0.00 g	-
CTG-15	0.00 f	0.00 g	0.00 h	-	-	0.13 dB	1.00 gAB	1.75 hA	7.18	0.026*	0.06 eB	0.50 gAB	0.88 gA	7.18
CP-15	8.00 cdB	9.00 deB	11.00 efA	7.00	0.027*	4.75 cC	7.50 efB	9.25 efA	25.55	0.001**	6.38 cdC	8.25 deB	10.13 deA	38.20
CTG-5	5.00 eC	10.00 cdeB	14.00 cdeA	25.24	0.001**	4.50 cC	11.00 cdB	14.25 cdA	46.09	0.000**	4.75 dC	10.50 cdB	14.13 cA	39.60
WS-10	6.00 deC	8.00 eB	12.00 defA	42.00	0.000**	3.63 cC	8.00 deB	10.54 eA	25.06	0.001**	4.81 dC	8.00 deB	11.27 dA	56.48
CP-10	9.00 bcB	12.00 cAB	15.00 cdA	11.17	0.009**	8.00 bC	11.75cB	13.83 dA	28.38	0.001**	8.50 bcC	11.88 cB	14.42 cA	17.00
WS-5	8.00 cdB	11.00 cdB	16.00 cA	14.45	0.005**	5.63 cC	12.00 bcB	16.00 cA	30.78	0.001**	6.81 cdC	11.50 cB	16.00 cA	23.50
CTG-10	6.00 deB	8.00 eAB	9.00 fgA	3.50	0.098	3.50 cB	7.00 efA	7.79 fA	35.62	0.000**	4.75 dB	7.50 eA	8.40 eA	46.11
WS-15	2.00 fB	5.00 fA	6.00 gA	14.18	0.005**	1.13 dB	4.46 fA	5.00 gA	31.18	0.001**	1.56 eB	4.73 fA	5.50 fA	30.46
CP-5	11.00 bC	17.00 bB	21.00 bA	39.81	0.000**	9.50 bC	15.00 bB	18.50 bA	28.50	0.001**	10.25 bC	16.00 bB	19.75 bA	38.11
Weedy	20.00 aC	32.00 aB	53.00 aA	58.39	0.000**	16.00 aC	30.00 aB	46.50 aA	61.24	0.000**	18.00 aC	31.00 aB	49.75 aA	83.19
Mean	7.54	11.18	15.09			5.16	9.79	13.04			6.35	10.49	14.06	
F	38.93	135.12	167.48			38.12	63.00	422.00			48.03	108.20	391.92	
P	0.000**	0.000**	0.000**			0.000**	0.000**	0.000**			0.000**	0.000**	0.000**	

* $p < 0.05$, ** $p < 0.01$.

CP, shredded paper; CTG, grass clippings; E, assessment; TRE, treatments; WS, wheat straw.

Lowercase letters indicate groupings among the applications, while uppercase letters indicate groupings within each application. Differences between means indicated by the same letter are not significant at the 0.05 level.

Table 6. Effect of mulching on *C. arvensis*.

CON.	2021 year					2022 year					Mean				
	1. E	2. E	3. E	F	p	1. E	2. E	3. E	F	p	1. E	2. E	3. E	F	p
Weed free	0.00 d	0.00 e	0.00 d	-	-	0.00 f	0.00 e	0.00 f	-	-	0.00 f	0.00 f	0.00 f	-	-
CTG-15	0.00d C	1.00 deB	3.00 cA	42.00	0.000**	0.00 fC	0.50 efC	1.63 efA	30.69	0.001**	0.00 fC	0.75 efB	2.31 deA	37.72	0.000**
CP-15	0.00 dB	3.00 cdA	3.00 cA	21.60	0.002**	0.00 fB	2.29 cdA	2.75 cdeA	31.00	0.001**	0.00 fB	2.65 cA	2.88 cdeA	29.36	0.001**
CTG-5	2.00 bcA	3.00 cdA	3.00 cA	2.28	0.183	1.0 deB	2.00 cdAB	3.00 cdeA	6.85	0.028*	1.50 eB	2.50 cAB	3.00 cdeA	4.80	0.057
WS-10	3.00 bB	5.00 bcA	5.00 bcA	8.00	0.020*	1.50 cdB	3.50 bcA	3.75 bcdA	15.64	0.004**	2.25 cdB	4.25 bcA	4.38 bcdeA	13.21	0.006**
CP-10	3.00 bA	5.00 bcA	6.00 bcA	3.818	0.085	2.00 cB	3.33 bcAB	4.00 bcdA	3.89	0.082	2.50 bcB	4.17 bcAB	5.00 bcdA	3.94	0.080
WS-5	2.00 bcB	5.00 bcA	6.00 bcA	18.90	0.003**	1.50 cdC	3.50 bcB	4.50 bcA	28.00	0.001**	1.75 deB	4.25 bcA	5.25 bcA	23.11	0.002**
CTG-10	0.00 dC	2.00 deB	4.00 cA	33.88	0.001**	0.00 fC	1.50 deB	2.63 deA	39.96	0.000**	0.00 fC	1.75 deB	3.31 cdeA	40.29	0.000**
WS-15	1.00 cdC	2.00 deB	3.00 cA	16.00	0.004**	0.50 efB	1.50 deAB	2.25 deA	6.52	0.031*	0.75 fB	1.75 deA	2.63 deA	10.56	0.011*
CP-5	3.00 bB	6.00 bA	7.00 bA	8.66	0.017*	3.00 bB	4.33 bAB	5.50 bA	8.55	0.017*	3.00 bB	5.17 bA	6.25 bA	8.74	0.017*
Weedy	6.00 aA	9.00 aA	11.00 aA	2.09	0.205	4.00 aA	7.00 aA	7.50 aA	2.86	0.134	5.00 aA	8.00 aA	9.25 aA	2.54	0.158
Mean	2.09	4.09	5.00			1.23	2.68	3.41			1.66	3.38	4.20		
F	27.270	15.193	10.15			20.870	17.562	12.725			45.580	16.986	11.173		
P	0.000**	0.000**	0.000**			0.000**	0.000**	0.000**			0.000**	0.000**	0.000**		

* $p < 0.05$, ** $p < 0.01$.

CP, shredded paper; CTG, grass clippings; E, assessment; TRE, treatments; WS, wheat straw.

Lowercase letters indicate groupings among the applications, while uppercase letters indicate groupings within each application. Differences between means indicated by the same letter are not significant at the 0.05 level.

Table 7. Effect of mulching on *X. strumarium*.

XAN	2021 year					2022 year					Mean				
	1. E	2. E	3. E	F	p	1. E	2. E	3. E	F	p	1. E	2. E	3. E	F	p
TRE															
Weed free	0.00 b	0.00 b	0.00 c	-	-	0.00 b	0.00 b	0.00 b	-	-	0.00 b	0.00 b	0.00 c	-	-
CTG-15	0.00 b	0.00 b	0.00 c	-	-	0.00 b	0.00 b	0.00 b	-	-	0.00 b	0.00 b	0.00 c	-	-
CP-15	0.00 b	0.00 b	0.00 c	-	-	0.00 b	0.00 b	0.00 b	-	-	0.00 b	0.00 b	0.00 c	-	-
CTG-5	0.00 b	0.00 b	0.00 c	-	-	0.00 bA	0.00 bA	0.13 bA	3.000	0.125	0.00 bA	0.00 bA	0.06 cA	3.000	0.125
WS-10	0.00 b	0.00 b	0.00 c	-	-	0.00 bA	0.00 bA	0.04 bA	1.000	0.422	0.00 bA	0.00 bA	0.02 cA	1.000	0.422
CP-10	0.00 b	0.00 b	0.00 c	-	-	0.00 bA	0.25 bA	0.46 bA	3.640	0.092	0.00 bA	0.13 bA	0.23 cA	3.640	0.092
WS-5	0.00 b	0.00 b	0.00 c	-	-	0.00 bA	0.25 bA	0.25 bA	3.000	0.125	0.00 bA	0.13 bA	0.13 cA	3.000	0.125
CTG-10	0.00 b	0.00 b	0.00 c	-	-	0.00 bA	0.00 bA	0.13 bA	3.000	0.125	0.00 bA	0.00 bA	0.06 cA	3.000	0.125
WS-15	0.00 b	0.00 b	0.00 c	-	-	0.00 b	0.00 b	0.00 b	-	-	0.00 b	0.00 b	0.00 c	-	-
CP-5	0.00 bB	1.00 bA	1.00 bA	24.000	0.001**	0.00 bA	0.75 bA	1.00 bA	4.875	0.055	0.00 bA	0.88 bA	1.00 bA	9.500	0.014*
Weedy	3.00 aB	6.00 aA	8.00 aA	11.400	0.009**	2.50 aA	4.00 aA	5.00 aA	1.583	0.280	2.75 aB	5.00 aAB	6.50 aA	5.344	0.046*
Mean	0.36	0.81	0.90			0.23	0.48	0.64			0.29	0.64	0.77		
F	27.00	26.437	3043.2			18.75	10.85	16.32			22.68	17.77	104.69		
P	0.000**	0.000**	0.000**			0.000**	0.000**	0.000**			0.000**	0.000**	0.000**		

* $p < 0.05$; ** $p < 0.01$.

CP, shredded paper; CTG, grass clippings; E, assessment; TRE, treatments; WS, wheat straw.

Lowercase letters indicate groupings among the applications, while uppercase letters indicate groupings within each application. Differences between means indicated by the same letter are not significant at the 0.05 level.

Table 8. Effect of mulching on other weed species.

Other	2021 year					2022 year					Mean					
	TRE	1. E	2. E	3. E	F	p	1. E	2. E	3. E	F	p	1. E	2. E	3. E	F	p
Weed free		0.00 e	0.00 d	0.00 c	-	-	0.00 d	0.00 d	0.00 e	-	-	0.00 e	0.00 d	0.00c	-	-
CTG-15		0.00 eA	0.00 dA	0.08 cA	1.00	0.422	0.00 d	0.00 d	0.00 e			0.00 e	0.00 d	0.04 c	1.00	0.422
CP-15		0.00 eB	0.17 cdB	0.67 bcA	10.40	0.011*	0.00 dB	0.00 dB	0.50 bcdA	12.00	0.008**	0.00 e	0.08 d	0.58 c	15.63	0.004**
CTG-5		1.00 bA	1.67 bA	1.75 bA	1.49	0.298	1.00 bA	1.50 bA	1.50 bcA	1.00	0.422	1.00 b	1.58 b	1.63 b	1.34	0.329
WS-10		0.08 deB	0.92 bcA	1.00 bcA	55.50	0.000**	0.25 cdB	1.00 bcA	1.25 bcdA	13.00	0.007**	0.17 de	0.96 bc	1.13 bc	26.64	0.001**
CP-10		0.08 deA	0.33 cdA	0.67 bcA	2.46	0.165	0.00 B	0.25 cdAB	0.50 bcdA	4.50	0.064	0.04 e	0.29 cd	0.58 bc	3.25	0.110
WS-5		0.83 bcB	1.50 bA	1.92 bA	16.12	0.004*	0.75 bcB	1.50 bA	1.75 bA	13.00	0.007**	0.79 bc	1.50 b	1.83 b	16.86	0.003**
CTG-10		0.33 cdeA	0.33 cdA	0.58 bA	0.50	0.630	0.25 cdA	0.25 cdA	0.50 bcdA	1.00	0.422	0.29 cde	0.29 cd	0.54 bc	0.70	0.531
WS-15		0.00 A	0.17 cdA	0.17 cA	2.00	0.216	0.00 dA	0.25 cdA	0.25 deA	1.50	0.296	0.00 e	0.21 cd	0.21 c	1.78	0.246
CP-5		0.58 bcdB	1.42 bA	1.83 bA	9.72	0.013*	0.75 bcB	1.25 bAB	1.50 bcA	3.50	0.098	0.67 bcd	1.33 b	1.67 b	7.46	0.024*
Weedy		2.67 aB	7.00 aA	9.33 aA	13.43	0.006**	2.00 aB	6.50 aA	8.00 aA	12.10	0.008**	2.33 a	6.75 a	8.67 a	13.13	0.006**
Mean		0.50	1.20	1.60			0.45	1.14	1.43			0.48	1.18	1.53		
F		22.658	68.389	31.962			8.750	40.513	34.785			15.341	55.037	34.075		
P		0.000**	0.000**	0.000**			0.000**	0.000**	0.000**			0.000**	0.000**	0.000**		

* $p < 0.05$; ** $p < 0.01$.

CP, shredded paper; CTG, grass clippings; E, assessment; TRE, treatments; WS, wheat straw.

Lowercase letters indicate groupings among the applications, while uppercase letters indicate groupings within each application. Differences between means indicated by the same letter are not significant at the 0.05 level.

pronounced effect on their density. A slight reduction in the density of these species was observed with mulch applied at 5 cm thickness, but this reduction remained limited. However, mulch applications at thicknesses of ≥ 10 cm significantly reduced the density of these species, providing effective control at these levels. Similar effects were observed on other weed species in the trial area, with weed densities decreasing significantly as mulch thickness increased. Overall, all mulch materials proved to be effective methods for suppressing weed growth. Furthermore, thicker mulch applications resulted in more effective weed suppression, leading to greater success in weed control. Compared with the control plots, weed densities in the mulched plots were significantly lower, demonstrating that mulch applications are a successful method for weed management (Tables 5–8).

Previous studies, such as those by Kaya (2011) and Jodaugiene et al. (2006), have shown that mulch thickness reduces weed density, with particularly greater effects on annual weeds. Similarly, Kosterna (2014) reported that higher mulch doses enhance weed control, findings consistent with our study. Kaya (2011) and Döring et al. (2005) also emphasised that straw and other mulch types are effective in controlling weeds, but straw mulch may have limited effects, especially when applied in low amounts. In this study, while *S. halepense* was able to maintain high density at even < 5 cm mulch applications, the effect of mulch thickness was more pronounced on species such as *X. strumarium* and *C. arvensis*. Significant reductions in weed density

were observed, especially with mulch thicknesses of ≥ 10 cm. Moreover, studies by Genger et al. (2018) and Marble et al. (2019) confirmed the ability of straw mulch to suppress broadleaf weeds.

Effect of mulching on weed dry weight

Significant differences were observed in the dry weights of weeds in eggplant fields during both years ($F = 116.782$, $p < 0.01$ in 2021; $F = 155.467$, $p < 0.01$ in 2022). Weed dry weights varied depending on the type and thickness of the mulch materials (Table 9).

According to the data, significant differences were observed among mulch material types and thicknesses in terms of weed control efficacy. It was found that various mulch applications significantly reduced weed dry weight over the 2 years, and these effects were found to be statistically significant ($p < 0.001$). When considering the average of both years, the lowest weed dry weights and the highest efficacy rates compared with the weedy control plots were obtained with the Paper 3 application ($45.13 \text{ g} \cdot \text{m}^{-2}$ weed dry weight and 86.34% efficacy rate). Based on the average weed control efficacy, the most effective applications were CP 15 cm, CP 10 cm and WS 15 cm, respectively. This indicates that thicker paper and straw mulches were particularly successful in controlling weeds (Table 9).

The findings align with the study by Gómez De Barreda et al. (2023), which identified three factors influencing the effectiveness of mulch management: mulch rate, installation timing and replacement rate. In this study, mulch thickness was found to be a

Table 9. Effect of mulching on weed dry weight.

Treatments	2022		2023		Means	
	Weed dry weights (g)	Effect (%)	Weed dry weights (g)	Effect (%)	Weed dry weights (g)	Effect (%)
CTG-5 cm	210.13 $\pm$ 14.72 b	17.11	206.38 $\pm$ 23.41 b	49.34	208.26 $\pm$ 15.86 b	36.97
CTG-10 cm	160.70 $\pm$ 17.79 d	36.61	165.70 $\pm$ 14.72 c	59.32	163.20 $\pm$ 9.35 c	50.61
CTG-15 cm	115.20 $\pm$ 21.60 f	54.56	99.80 $\pm$ 4.09 de	75.50	107.50 $\pm$ 12.62 d	67.47
CP-5	143.30 $\pm$ 7.25 e	43.47	186.80 $\pm$ 14.39 bc	54.14	165.05 $\pm$ 7.13 c	50.05
CP-10	66.50 $\pm$ 14.71 g	73.77	77.75 $\pm$ 14.93 ef	80.91	72.13 $\pm$ 14.77 e	78.17
CP-15	42.00 $\pm$ 14.14 h	83.43	48.25 $\pm$ 17.97 g	88.16	45.13 $\pm$ 15.99 f	86.34
WS-5	182.19 $\pm$ 12.63 c	28.13	203.43 $\pm$ 16.82 b	50.06	192.81 $\pm$ 7.83 b	41.65
WS-10	122.00 $\pm$ 10.80 f	51.87	114.78 $\pm$ 10.64 d	71.82	118.39 $\pm$ 5.98 d	64.17
WS-15	60.00 $\pm$ 21.20 gh	76.33	60.00 $\pm$ 19.58 fg	85.27	60.00 $\pm$ 19.57 de	81.84
Weed	253.50 $\pm$ 4.72 a	0.00	407.37 $\pm$ 34.27 a	0.00	330.44 $\pm$ 15.70 a	0.00
Weed-free	0.00 $\pm$ 0.00 i	100.00	0.00 $\pm$ 0.00 h	100.00	0.00 $\pm$ 0.00 f	100.00
Mean	123.23 $\pm$ 75.04		142.75 $\pm$ 108.20		132.99 $\pm$ 89.84	
F	116.782		155.467		214.863	
p-value	0.000**		0.000**		0.000**	

** $p < 0.01$.

CP, shredded paper; CTG, grass clippings; WS, wheat straw.

Lowercase letters indicate groups formed among the applications, while uppercase letters denote groups formed within evaluations for each application. Differences between means indicated by the same letter are not significant at the 0.05 level. Values are presented as mean $\pm$ standard deviation.

significant factor affecting weed control. Thicker mulch applications were more effective in suppressing weed growth. This result parallels the findings of Jodaugiene et al. (2006) and Kaya (2011), which also demonstrated the effectiveness of thicker mulch layers. The impact of different mulch materials on weed control, as observed in Grassbaugh et al. (2004), is consistent with our findings. Hammermeister (2016) also noted that mulch can fully or partially control weeds in agricultural fields. In this study, weeds were predominantly suppressed. Moreover, the studies by Ateş and Uygur (2013) and Gürbüz et al. (2021) emphasised the positive effects of mulch on weed control, while highlighting that this effect can vary depending on the type and thickness of the mulch material. Similar to the findings of Kaya (2011) and Döring et al. (2005), this study observed limited effects of straw mulch at lower amounts. This aligns with the literature indicating that mulch was less effective against *S. halepense* but more effective against other weed species. Finally, studies by Genger et al. (2018) and Marble et al. (2019) confirmed the ability of straw mulch to suppress broadleaf weeds. Accordingly, this study found that straw mulch could be effective under certain conditions, with its effect becoming more pronounced with increased thickness.

Effects of mulching on eggplant yield and yield components

Significant differences were found among all parameters evaluated in the study (plant height, fruit count per plant, fruit weight, yield per plant and overall yield) across the applications ($p < 0.001$), indicating that each application had different effects on plant performance (Table 10).

Yield differences were also observed according to mulch types and thicknesses. While grass applications generally provided higher yields than other mulch types, Paper and Straw applications also provided higher yield results than the control plot. The highest yield in the study was obtained in the CTG-15 cm ($83.20 \text{ t} \cdot \text{ha}^{-1}$) application in 2021. This value is approximately 75% higher than the control plot. These results are consistent with previous studies emphasising the weed-suppressive effects of mulch materials (Jodaugiene et al., 2006; Kaya, 2011; Genger et al., 2018). The eggplant yield was higher in 2021. The slightly higher temperature in 2021 compared with 2022 (Table 1) may explain this difference. This observation is consistent with the findings of Adamczewska-Sowińska et al. (2016), who state that eggplant growth and yield are significantly influenced by air temperature. When the average values are considered, CTG-15 cm application provided the highest yield with $80.86 \text{ t} \cdot \text{ha}^{-1}$. When compared with the control (weedy) application, a yield increase of approximately 75% was achieved in Grass 3 application, which had the highest yield. These findings align with previous research on mulch-based weed control and yield enhancement (Hussain et al., 2022; Tarrant et al., 2024). In addition, Paper and Straw applications generally

provided higher yields than the control application. For example, the average yield in the WS 10 cm application was $74.17 \text{ t} \cdot \text{ha}^{-1}$, which is approximately 60% higher than the control application. As a result, it was clearly seen in the study that mulch applications had a positive effect on yield. In addition, increasing the mulch thickness further increased the yield and revealed that mulch applications positively affected plant development. These findings show that mulches such as grass, paper and straw are an effective strategy, especially for weed control and increasing yield (Table 10). Hashimi et al. (2019) reported that mulching had positive effects on eggplant yield. Pirboneh et al. (2012) stated that straw mulch provided the highest fruit yield and these findings were similar to the current study. Gürbüz et al. (2021) also stated that mowed weed wastes provided positive effects on yield when used as mulch and observed yield increases. In addition, Ateş (2007) and other researchers emphasised that straw mulch is effective in increasing yield. In the study, it was observed that plant development and yield increased with increasing mulch thickness. Studies conducted by Genger et al. (2018) and Marble et al. (2019) also stated that straw mulch suppressed broadleaf weeds and increased yield. Syed Shahnaz (2023) emphasised the potential of mulches to increase plant yield while providing cool and moist soil. Another study showing that yield losses are caused by weeds was conducted by Marques et al. (2017), and in this study, weeds were found to reduce eggplant yield by 78%. Similarly, Almhemed and Ustuner (2022) stated that they increased the yield loss caused by weeds by up to 92.52% compared with the control plot. Mulching creates a physical barrier that prevents weed emergence by blocking sunlight and reducing temperature fluctuations on the soil surface (Iqbal et al., 2020). Organic mulches such as CTG and WS provide additional benefits by improving soil moisture retention, increasing nutrient availability through decomposition, and promoting microbial diversity (Neal et al., 2015; Omidvar et al., 2023). However, the effectiveness of mulching is affected by the type and thickness of mulch used. In this study, the most effective treatment was 15 cm thick CTG mulch (CTG-15). Thicker mulch layers provide a more effective barrier to light penetration, which provides success in weed control. This finding is consistent with previous studies (Jodaugiene et al., 2006). CP and WS applications were also found to be effective, but their performances were relatively lower than CTG. This may be due to differences in the material structure, decomposition rate and moisture retention capacity. Similar results were reported by Genger et al. (2018) and Marble et al. (2019), who reported that straw mulch in particular was less effective at low thickness levels. Interestingly, this study showed that *S. halepense* maintained its high densities even with mulch applications of 15 cm thickness, highlighting the species' resistance and aggressive growth habit. This result is consistent with previous studies indicating that

Table 10. Effects of mulching on eggplant yield and yield components.

Treatments	Plant height (cm)	Fruits per plant (fruit · plant ⁻¹)	Fruit weight (g)	Yield per plant (kg)	Yield (t · ha ⁻¹)
2021					
CTG-5 cm	50.60 ± 1.41 h	17.85 ± 0.08 e	140.03 ± 1.63 e	2.50 ± 0.16 d	65.25 ± 1.54 d
CTG-10 cm	72.14 ± 1.41 c	19.59 ± 0.04 b	155.11 ± 1.65 b	3.04 ± 0.16 abc	78.99 ± 1.51 b
CTG-15 cm	75.20 ± 2.16 b	19.74 ± 0.08 a	162.05 ± 1.42 a	3.20 ± 0.22 a	83.20 ± 0.81 a
CP-5	49.45 ± 0.71 h	17.33 ± 0.06 f	132.13 ± 2.18 f	2.29 ± 0.08 d	59.54 ± 0.40 g
CP-10	64.70 ± 2.94 e	19.43 ± 0.06 c	144.08 ± 0.83 d	2.80 ± 0.16 c	72.55 ± 0.64 d
CP-15	76.80 ± 0.82 ab	19.45 ± 0.04 c	154.17 ± 1.46 b	3.00 ± 0.14 abc	78.00 ± 1.06 b
WS-5	54.70 ± 1.6 3 g	17.02 ± 0.07 g	138.07 ± 2.16 e	2.35 ± 0.12 d	61.10 ± 0.70 f
WS-10	78.30 ± 0.00 a	19.67 ± 0.08 ab	160.06 ± 1.48 a	3.15 ± 0.28 ab	81.90 ± 0.70 a
WS-15	62.30 ± 1.41 f	19.32 ± 0.07 c	150.04 ± 2.12 c	2.90 ± 0.16 bc	75.40 ± 0.32 c
Weed	43.12 ± 2.16 i	15.87 ± 0.09 h	126.02 ± 1.63 g	2.01 ± 0.16 e	52.26 ± 0.81 h
Weed-free	68.40 ± 1.41 d	19.24 ± 0.05 d	148.10 ± 1.43 c	2.85 ± 0.12 c	74.10 ± 0.70 c
Mean	63.25 ± 11.86	18.59 ± 1.29	146.35 ± 11.17	2.74 ± 0.41	71.11 ± 0.97
F	219.791	159.572	186.858	21.177	483.703
p-value	0.000**	0.000**	0.000**	0.000**	0.000**
2022					
CTG-5 cm	52.68 ± 5.19 f	15.45 ± 0.62 c	150.00 ± 4.16 bcd	2.32 ± 0.08 de	60.23 ± 2.23 de
CTG-10 cm	70.09 ± 3.10 abc	19.35 ± 0.65 a	155.00 ± 3.55 abc	3.00 ± 0.14 a	78.00 ± 3.82 a
CTG-15 cm	71.68 ± 6.22 bc	18.60 ± 0.75 ab	162.50 ± 6.45 a	3.02 ± 0.10 a	78.52 ± 2.62 a
CP-5	51.55 ± 5.04 f	15.10 ± 0.61 c	140.75 ± 5.61 e	2.12 ± 0.05 e	55.20 ± 1.35 e
CP-10	63.90 ± 2.79 de	17.88 ± 0.29 b	147.25 ± 5.12 cde	2.63 ± 0.12 b	68.45 ± 3.27 b
CP-15	80.05 ± 5.13 a	19.60 ± 1.03 a	151.25 ± 6.89 bcd	2.97 ± 0.24 a	77.12 ± 6.25 a
WS-5	51.73 ± 3.93 f	15.55 ± 0.81 c	140.25 ± 5.56 e	2.18 ± 0.09 de	56.65 ± 2.55 de
WS-10	75.33 ± 5.39 ab	17.55 ± 1.72 b	145.50 ± 4.50 de	2.56 ± 0.29 bc	66.45 ± 7.57 bc
WS-15	60.73 ± 3.26 e	18.88 ± 1.07 ab	158.25 ± 2.36 ab	2.99 ± 0.13 a	77.62 ± 3.62 a
Weed	41.22 ± 3.69 g	12.50 ± 0.60 d	123.75 ± 8.53 f	1.54 ± 0.06 f	40.13 ± 1.60 f
Weed-free	66.25 ± 2.21 cde	16.20 ± 0.81 c	145.75 ± 3.30 de	2.36 ± 0.13 cd	61.39 ± 3.54 cd
Mean	62.29 ± 12.10	16.97 ± 2.26	147.30 ± 11.09	2.52 ± 0.47	65.43 ± 1.22
F	29.872	24.307	15.038	38.455	38.455
p-value	0.000**	0.000**	0.000**	0.000**	0.000**
Mean					
CTG-5 cm	51.64 ± 2.86 f	16.70 ± 0.96 cd	145.02 ± 3.78 cd	2.41 ± 0.07 e	62.74 ± 1.28 d
CTG-10 cm	71.11 ± 1.92 c	19.48 ± 0.85 a	155.06 ± 5.30 ab	3.02 ± 0.14 ab	78.49 ± 2.45 ab
CTG-15 cm	73.44 ± 3.59 bc	19.17 ± 0.49 a	162.28 ± 7.21 a	3.11 ± 0.14 a	80.86 ± 1.61 a
CP-5	50.50 ± 2.59 f	16.26 ± 1.03 d	136.44 ± 6.42 e	2.21 ± 0.04 e	57.37 ± 0.70 e
CP-10	64.30 ± 2.83 de	18.63 ± 1.07 ab	145.67 ± 6.18 cd	2.72 ± 0.11 cd	70.50 ± 1.95 d
CP-15	78.43 ± 2.80 a	19.54 ± 0.48 a	152.71 ± 7.31 bc	2.98 ± 0.15 ab	77.56 ± 3.26 b
WS-5	53.21 ± 1.55 f	16.30 ± 1.00 d	139.16 ± 4.49 de	2.26 ± 0.11 e	58.87 ± 1.58 e
WS-10	76.81 ± 2.69 ab	18.61 ± 1.35 ab	152.78 ± 4.29 bc	2.85 ± 0.26 bc	74.17 ± 4.04 c
WS-15	61.51 ± 2.22 e	19.10 ± 0.48 a	154.15 ± 3.83 b	2.94 ± 0.09 ab	76.51 ± 1.74 bc
Weed	42.17 ± 2.62 g	14.23 ± 0.84 e	124.89 ± 3.30 f	1.78 ± 0.11 f	46.19 ± 0.44 f
Weed-free	67.33 ± 0.62 d	17.72 ± 0.37 bc	146.93 ± 2.09 bcd	2.61 ± 0.07 d	67.74 ± 1.54 d
Mean	62.77 ± 11.78	17.79 ± 1.81	146.82 ± 11.01	2.63 ± 0.42	68.27 ± 1.06
F	91.245	15.582	16.080	38.814	104.424
p-value	0.000**	0.000**	0.000**	0.000**	0.000**

** $p < 0.01$.

CP, shredded paper; CTG, grass clippings; WS, wheat straw.

Differences between means indicated by the same letter are not significant at the 0.05 level. Values are presented as mean ± standard deviation.

perennial weeds are generally more difficult to control with mulch than annual species (Kaya, 2011; Marques et al., 2017). By contrast, *X. strumarium* and *C. arvensis* were effectively suppressed with mulch thicknesses of ≥ 5 cm. This finding suggests that the effectiveness of mulching may vary depending on the weed species present. The findings also show that CTG (CTG-15) are particularly effective in increasing eggplant yield. This can be explained by the fact that CTG retain soil moisture during the decomposition process and increase nutrient release. It is also supported by previous studies that organic mulches contribute to soil health and productivity over time (Gürbüz et al., 2021; Syed Shahnaz, 2023). In addition, the positive correlation between mulch thickness and yield increase suggests that thicker layers are beneficial for increasing productivity. Comparative studies on plastic and organic mulches generally emphasise the superior performance of plastic mulches in changing soil temperature and moisture retention (Tarara, 2000; Sabatino et al., 2018). However, the environmental disadvantages of plastic mulches, especially disposal and degradation issues, necessitate the search for sustainable alternatives (Steinmetz et al., 2016; Di Miceli et al., 2024). The findings of this study indicate that organic mulches, especially CTG, offer a viable alternative to plastic mulches by providing effective weed control and yield increase without adverse environmental impacts. These data clearly show the great effect of weed control on yield and how mulch applications can prevent these losses.

Effects of mulching on eggplant fruit quality and marketable yield

A range of significant differences were observed in all fruit quality parameters given evaluation, including fruit length, fruit diameter, fruit firmness, marketable yield and unmarketable yield across the different mulch applications ($p < 0.001$). These findings suggest that the type and thickness of mulch have substantial effects on fruit quality and productivity (Table 11).

Mulching had a significant impact on the quality of eggplant fruit and the resulting marketable yield. The longest fruits were recorded in the CTG-15 cm treatment, with a mean length of 22 cm, whereas the shortest fruits were observed in the weedy control, measuring 12 cm. In a similar manner, the fruit diameter was found to be greatest in the CTG-15 cm (10 cm) group, and least in the weedy control (4 cm). Furthermore, the mulching treatments, specifically CTG-15 cm, CP-15 cm and WS-15 cm, exhibited the highest levels of fruit firmness ($4.5 \text{ kg} \cdot \text{cm}^{-2}$). By contrast, the weedy control treatment demonstrated the lowest levels of firmness ($2.0 \text{ kg} \cdot \text{cm}^{-2}$). With regard to marketable yield, the WS-15 cm treatment yielded the highest ($71.62 \text{ t} \cdot \text{ha}^{-1}$), followed by CTG-15 cm ($71.01 \text{ t} \cdot \text{ha}^{-1}$) and CP-15 cm ($70.26 \text{ t} \cdot \text{ha}^{-1}$). This suggests that thicker mulch layers are conducive to enhanced productivity. Conversely, the weedy control treatment resulted in the

lowest marketable yield ($29.39 \text{ t} \cdot \text{ha}^{-1}$), demonstrating significant yield losses due to weed competition. Unmarketable yield exhibited a comparable trend, with the maximum losses recorded in the weedy control ($10.75 \text{ t} \cdot \text{ha}^{-1}$), while the WS-15 cm treatment exhibited the lowest ($6.00 \text{ t} \cdot \text{ha}^{-1}$), underscoring the efficacy of mulching in mitigating fruit defects. The findings of this study demonstrate that increasing mulch thickness has a dual impact on fruit yield. On the one hand, it enhances fruit size and firmness, and on the other, it reduces unmarketable yield by minimising the adverse effects of weed competition and environmental stress. The utilisation of CTG, CP and WS, particularly at a thickness of 15 cm, has been demonstrated to be the most efficacious in enhancing the overall quality and yield of eggplants. The present study's findings on the positive impact of mulching on eggplant yield and quality are consistent with the existing literature. For instance, Carter and Johnson's (1988) study observed that various mulching materials significantly enhanced eggplant growth and development. A similar outcome was reported in a study by Memon et al. (2017), which found that mulching brinjal (eggplant) with materials such as transparent foil and polyethylene film resulted in substantial yield increases. Furthermore, research conducted by Carter and Johnson (1988) demonstrated that the use of different mulching materials had a positive influence on eggplant production. The findings of the present study demonstrate that mulch application is a successful strategy for enhancing eggplant yield and quality. Specifically, the results highlight the significant impact of mulch on weed suppression and yield improvement, with grass, paper and straw mulches promoting plant growth and increasing productivity. Additionally, mulch thickness was found to play a crucial role, as thicker mulch layers further suppressed weeds and contributed to higher yields. The findings emphasise the necessity of selecting appropriate mulch materials and optimising thickness to ensure the maximisation of both weed control and agricultural productivity.

Multivariate analysis of parameters and applications

There is a strong positive relationship between weed dry weight and weed density ($r = 0.934$, $p < 0.001$). However, weed dry weight and density show negative relationships with eggplant yield and yield components. Similarly, with weed density, the highest negative relationship was observed with yield per plant ($r = -0.745$, $p = 0.005$), and the lowest negative relationship was with plant height ($r = -0.707$, $p = 0.015$). For weed dry weight, the highest negative relationship with weed dry weight was found between yield per plant ($r = -0.764$, $p = 0.006$), and the lowest negative relationship was found with fruit number per plant ($r = -0.674$, $p = 0.023$). These results indicate that an increase in weed density and dry weight negatively affects eggplant growth and yield (Figure 2).

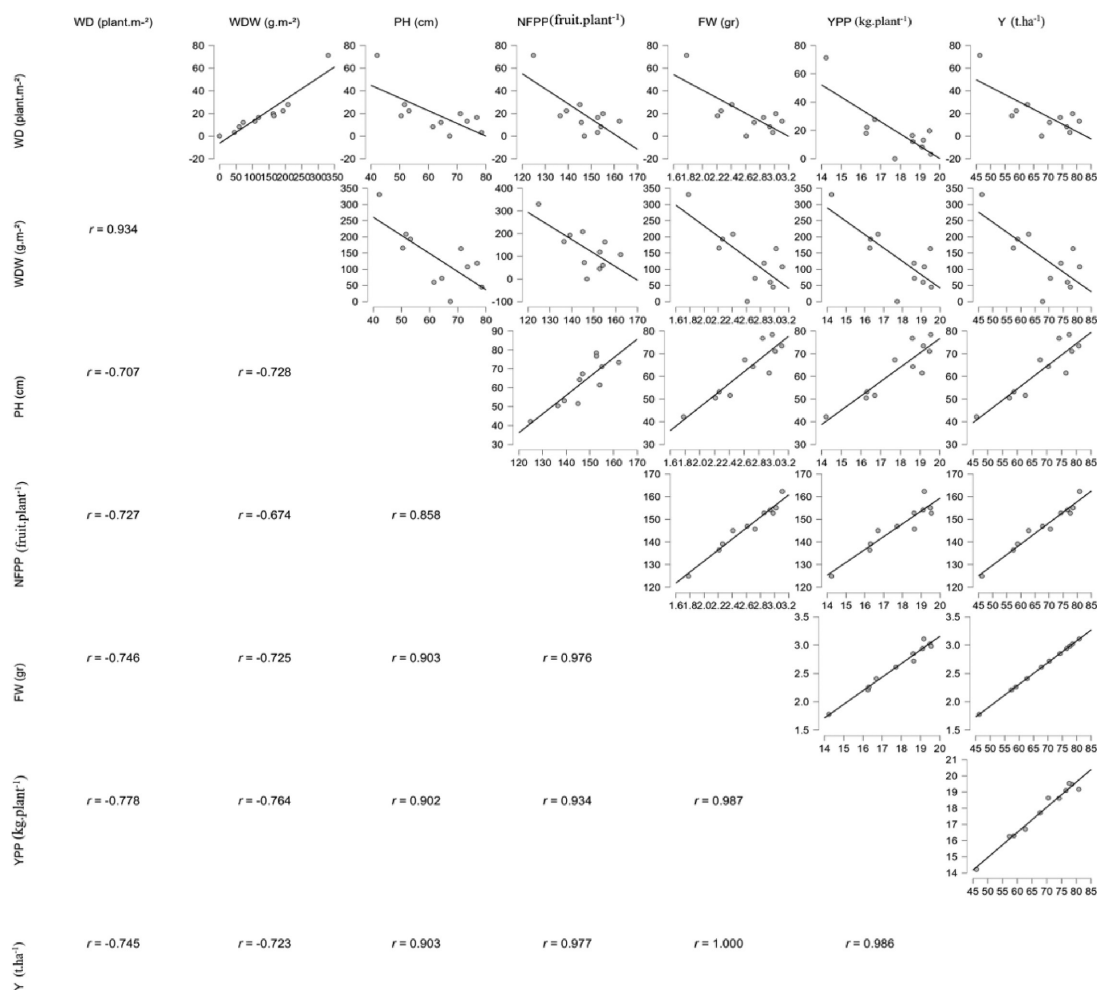
Table 11. Effects of mulching on eggplant fruit quality and marketable yield.

Treatments	Fruit length (cm)	Fruit diameter (cm)	Fruit firmness (kg · cm ⁻²)	Marketable yield (t · ha ⁻¹)	Unmarketable yield (t · ha ⁻¹)
CTG-5 cm	17 ± 0.18 f	6 ± 0.09 e	4.0 ± 0.01 b	51.20 ± 0.90 g	9.03 ± 0.11 b
CTG-10 cm	18 ± 0.09 e	7 ± 0.04 d	4.0 ± 0.02 b	70.30 ± 1.40 c	7.70 ± 0.01 e
CTG-15 cm	22 ± 0.07 a	10 ± 0.06 a	4.5 ± 0.04 a	71.01 ± 1.01 b	7.51 ± 0.04 f
CP-5 cm	16 ± 0.06 g	6 ± 0.06 e	3.5 ± 0.04 c	45.92 ± 2.04 i	9.28 ± 0.03 b
CP-10 cm	18 ± 0.10 e	6 ± 0.03 e	4.0 ± 0.03 b	60.45 ± 1.50 d	8.01 ± 0.01 d
CP-15 cm	20 ± 0.09 c	8 ± 0.04 c	4.5 ± 0.05 a	70.26 ± 0.81 c	6.87 ± 0.05 j
WS-5 cm	16 ± 0.09 g	7 ± 0.06 d	3.0 ± 0.06 d	47.85 ± 0.75 h	8.81 ± 0.01 c
WS-10 cm	19 ± 0.80 d	8 ± 0.04 c	3.5 ± 0.02 c	59.39 ± 1.20 e	7.07 ± 0.02 h
WS-15 cm	21 ± 0.09 b	9 ± 0.03 b	4.5 ± 0.04 a	71.62 ± 0.90 a	6.00 ± 0.01 i
Weedy	12 ± 0.06 h	4 ± 0.07 f	2.0 ± 0.03 e	29.39 ± 2.40 j	10.75 ± 0.07 a
Weed-free	18 ± 0.05 e	6 ± 0.05 e	4.0 ± 0.03 b	54.09 ± 0.50 f	7.31 ± 0.03 g
Mean	17.93 ± 0.40	6.99 ± 0.24	3.77 ± 0.11	57.39 ± 1.94	8.06 ± 0.20
F	788.373	993.649	340.909	749.541	1051.650
p-value	0.000**	0.000**	0.000**	0.000**	0.000**

***p* < 0.01.

CP, shredded paper; CTG, grass clippings; WS, wheat straw.

Differences between means indicated by the same letter are not significant at the 0.05 level. Values are presented as mean ± standard deviation.

**Figure 2.** Correlations of weed density and dry weight with other parameters. WD, weed density; WDW, weed dry weights; PH, plant height; NFPP, number of fruits per; FW, fruit weight; YPP, yield per plant; Y, yield.

Heat map clustering clearly distinguished dependent/independent variables by separating them into two main clusters with a colour range (+1.5 to -1.5; from red to blue) indicating the obtained values (Figure 3). Among the main clusters, there were CP 5 cm, WS 5 cm and weedy control plot. Although clustering differed according to the mulch materials, especially plots with high thickness were in a cluster among themselves. The results obtained from heat map clustering revealed that although the mulch materials used in the study differed, they were effective in combating weeds, especially as the thickness increased.

As a result of the hierarchical analysis, applications were collected in two main groups. In the first group, the weedy control was located alone, while in the second group, applications with mulch materials spread in 5 cm thickness formed a group (Figure 4). In the network graph analysis, the thickness between the lines shows the strength of the relationships. Thinner or lighter lines indicate weaker relationships, and thicker lines indicate stronger relationships. Consistent with the heatmap clustering and hierarchical clustering, a clear distinction emerged. In this analysis, the weedy control group was

only slightly related to WS 5 cm. The other treatments were related to each other to some extent (Figure 4). The main findings from these analyses indicate that different treatments had different degrees of impact on eggplant yield and yield components, and that weed control in particular played an important role.

Principal component analysis was performed. In order to explain the variation rate, agronomic traits of eggplant and weed dry weight and density were distributed on a biplot pair (Figure 5). Accordingly, the first two components (PC1: 86.69% and PC2: 9.24%) explained 95.63% of the variability of the original data. Such a high explained variance clearly shows that principal component analysis can be successfully used to evaluate the effect of the estimated parameters together with the applications. The first component (PC1) was negatively correlated with weedy control (with a score of -5.57), CP-5 cm (with a score of -2.01), WS-5 cm (with a score of -1.89) and CTG-5 cm (with a score of -1.51), while it was positively correlated with other treatments (Figure 5).

Advanced analyses such as correlation, heat map clustering, hierarchical clustering, network plot analysis and principal component analysis that we

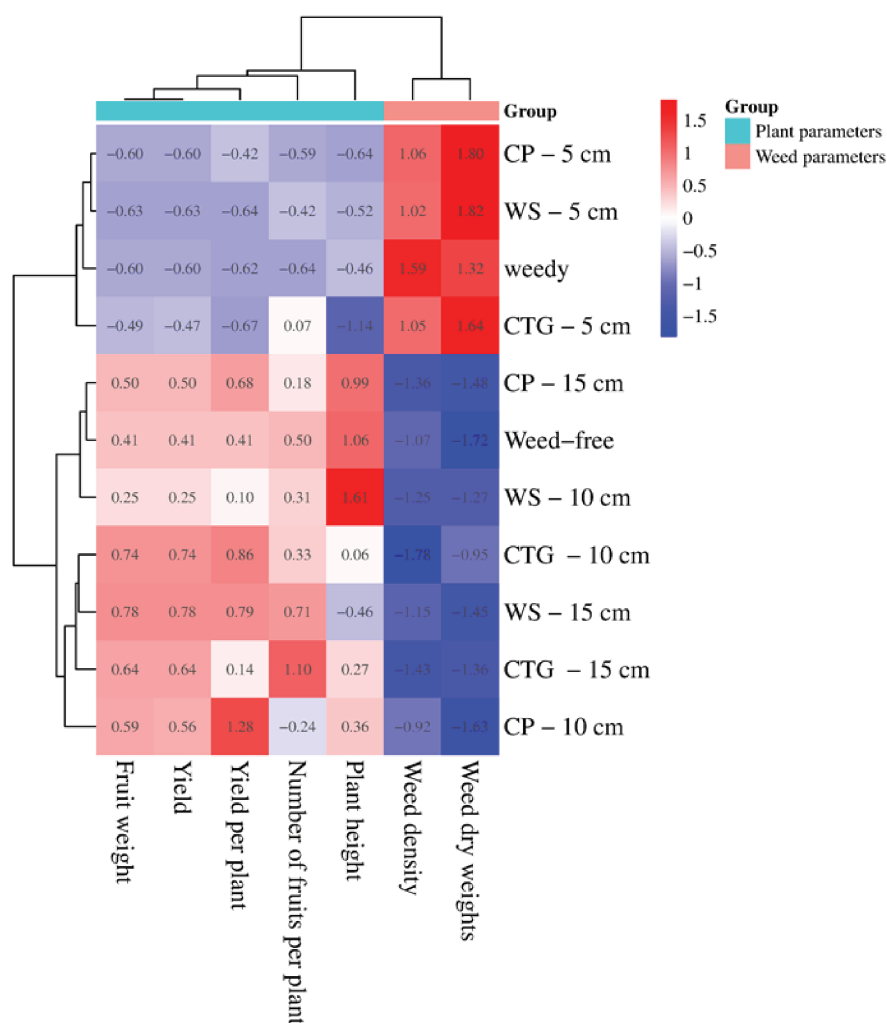


Figure 3. Heat map of the parameters corresponding to the applications (CP, CTG and WS). CP, shredded paper; CTG, grass clippings; WS, wheat straw.

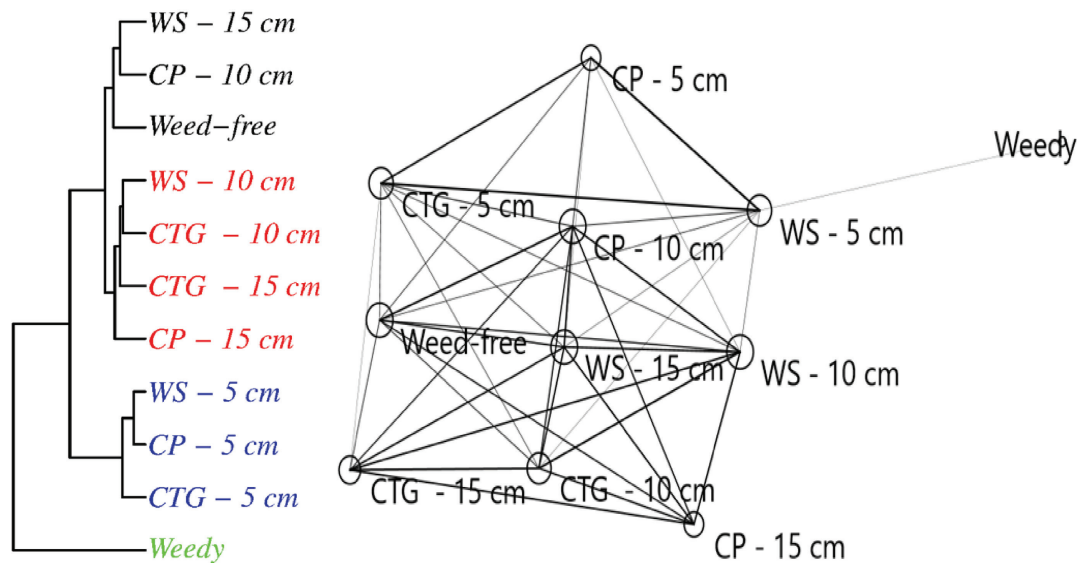


Figure 4. Applications (A) hierarchical clustering and (B) network graph analysis. CP, shredded paper; CTG, grass clippings; WS, wheat straw.

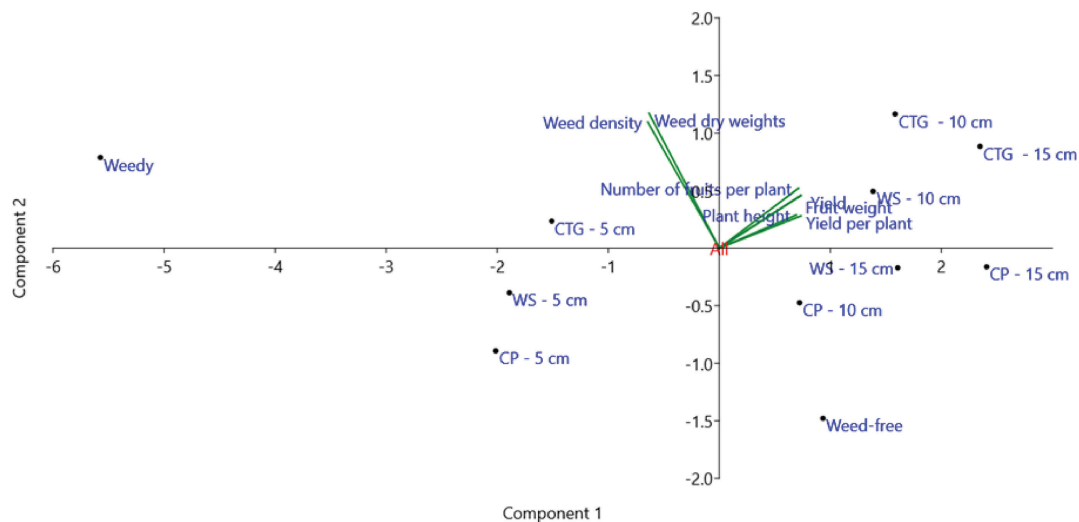


Figure 5. Principal component analysis of parameters and applications.

conducted on the mean values of the variables in the study support variance analysis, and can be considered to be very powerful in reducing the size of the variables considered for analysis by clustering and correlating the findings. In general, the effects and relationships between the applications and parameters are clearly stated.

CONCLUSIONS

Mulching was found to significantly reduce weed density and dry weight. The most effective weed control was provided by the CTG-15 cm mulch material, and weed density was found to be significantly lower in the mulched plots compared with the weedy control plots. Increasing the mulch thickness further reduced the weed density, and especially mulch thicknesses of ≥ 10 cm were effective on many weed species. In

particular, species such as *S. halepense* were able to reach high densities at even < 5 cm thick mulches, but species such as *X. strumarium* and *C. arvensis* were effectively controlled with mulches of ≥ 5 cm. In addition, significant increases were observed in eggplant yield with mulch applications. Grass application provided higher yields than other mulch types, and the yield of $83.20 \text{ t} \cdot \text{ha}^{-1}$ obtained with CTG-15 cm in 2021 was 75% higher than the control plot. The correlation analysis results revealed a negative relationship between weed density and dry weight and eggplant yield. As the biomass and density of weeds increased, a decrease was observed in the yield parameters of the eggplant plant.

This study fills the gap in the literature on the comparative effectiveness of various organic mulches at different thickness levels. It provides practical information for optimising mulch applications for

weed suppression and yield enhancement by examining three different thickness levels of CP, CTG and WS. While previous studies have largely focused on plastic mulches or a single mulch material, this study provides a more comprehensive evaluation of organic mulching strategies.

In conclusion, it was found that CTG applied at a thickness of 15 cm provided the most effective weed control and yield improvement. These findings support the general view that selecting appropriate mulch materials and thicknesses can increase productivity and sustainability in eggplant cultivation. Future studies should further investigate the long-term effects of organic mulches on soil health and investigate their applicability in different cropping systems and environmental conditions.

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AUTHOR CONTRIBUTIONS

S.Ç. and R.G. designed the experiments and collected the data. H.A. and R.G. designed the second year of the experiments and collected the data. H.A., V.O. and İ.K. performed the formal analysis and evaluation. R.G., H.A. and İ.K. wrote the original draft of the manuscript. V.O. was involved in visualisation of the manuscript. All authors reviewed and approved the final version of the manuscript.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

REFERENCES

- ABDRABBO, M. A. A., SALEH, S. M., AND HASHEM, F. A. (2017). Eggplant production under deficit irrigation and polyethylene mulch. *Egyptian Journal of Applied Sciences*, 32(7), 148–161, <https://doi.org/10.13140/RG.2.2.21904.40961>.
- ADAMCZEWSKA-SOWIŃSKA, K., KRYGIER, M., AND TURCZUK, J. (2016). The yield of eggplant depending on climate conditions and mulching. *Folia Horticulturae*, 28(1), 19–24, <https://doi.org/10.1515/fhort-2016-0003>.
- AHMAD, S., RAZA, M. A. S., SALEEM, M. F., ZAHEER, M. S., IQBAL, R., HAIDER, I., ASLAM, M. U., ALI, M., AND KHAN, I. H. (2020). Significance of partial root zone drying and mulches for water saving and weed suppression in wheat. *The Journal of Animal and Plant Sciences*, 30(1), 154–162, <https://doi.org/10.36899/japs.2020.1.0018>.
- AHMED, M. S. M., MANAL, M. H., MOULA, G. E., FARAG, A. A., AND ALY, A. M. M. (2016). Response of eggplant (*Solanum melongena* L.) to application of some organic fertilizers under different colors of plastic mulch. *Middle East Journal of Scientific Research*, 5(4), 636–646.
- AKKUŞ, M. (2015). The determination of irrigation programs of eggplant (*Solanum melongena* L.) at the different water levels and its effects on the yield components under semi-arid climate conditions (p. 87). MSc thesis. Turkey: Harran University.
- AL-BAYATI, H. M., AND HAMDOON, D. N. (2019). Response of eggplant *Solanum melongena* L. to soil mulching, organic and inorganic fertilizers on vegetative growth traits and yield grown under unheated plastic house. *IOP Conference Series: Earth and Environmental Science*, 388(1), 012075, <https://doi.org/10.1088/1755-1315/388/1/012075>.
- ALIYU, L., AND LAGOKE, S. T. O. (1995). Evaluation of herbicides for weed control in *Solanum aethiopicum* L. (scarlet eggplant) at Samaru, Nigeria. *Crop Protection*, 14(6), 479–481, [https://doi.org/10.1016/0261-2194\(95\)00020-m](https://doi.org/10.1016/0261-2194(95)00020-m).
- ALMHEMED, K., AND USTUNER, T. (2022). Assessment of some weed control methods efficacy and yield losses caused by weed in eggplant. *Fresenius Environmental Bulletin*, 31(8), 7514–7520.
- ALPTEKIN, H., AND GÜRBÜZ, R. (2022). The effect of organic mulch materials on weed control in cucumber (*Cucumis sativus* L.) cultivation. *Journal of Agriculture*, 5(1), 68–79, <https://doi.org/10.46876/ja.1126331>.
- ALTINOK, H. H. (2013). Fusarium species isolated from common weeds in eggplant fields and symptomless hosts of *Fusarium oxysporum* f. sp. *melongenae* in Turkey. *Journal of Phytopathology*, 161(5), 335–340, <https://doi.org/10.1111/jph.12074>.
- ARAMENDIZ-TATIS, H., CARDONA-AYALA, C., AND DE ORO, R. (2010). Periodo de interferencia de arvenses en el cultivo de berenjena (*Solanum melongena* L.). *Agroonomía Colombiana*, 28(1), 81–88.
- ATEŞ, S. (2007). *Determination of the effects of weed control methods and agroecological criters in organically grown eggplant and pepper* (p. 115). MSc thesis. Adana, Turkey: Çukurova University, Graduate School of Natural and Applied Sciences.
- ATEŞ, S., AND UYGUR, F. N. (2013). Ekolojik yöntemlerle yetiştirilen patlıcan ve biberde yabancı ot mücadele yöntemlerinin ve etkinliklerinin araştırılması. *Nevşehir Üniversitesi Fen Bilimleri Enstitüsü Dergisi*, 2(1), 69–77.
- BRAGA, P. C., SCALZO, R. L., DAL SASSO, M., LATTUADA, N., GRECO, V., AND FIBIANI, M. (2016). Characterization and antioxidant activity of semi-purified extracts and pure delphinidin-glycosides from eggplant peel (*Solanum melongena* L.). *Journal of Functional Foods*, 20, 411–421, <https://doi.org/10.1016/j.jff.2015.10.032>.
- CARTER, J. R., AND JOHNSON, C. D. (1988). Influence of different types of mulches on eggplant production. *HortScience*, 23(1), 143–145, <https://doi.org/10.21273/HORTSCI.23.1.143>.

- DI MICELI, G., IACUZZI, N., LETO, C., COZZOLINO, E., DI MOLA, I., OTTAIANO, L., MORI, M., AND BELLA, S. L. (2024). Assessment of yield and quality of eggplant (*Solanum melongena* L.) fruits improved by biodegradable mulching film in two different regions of southern Italy. *Agronomy*, 14(4), 867, <https://doi.org/10.3390/agronomy14040867>
- DÍAZ-PÉREZ, J. C. (2023). Degradation of plastic film mulch affects root zone temperature and fruit yield of eggplant (*Solanum melongena* L.). *Technology in Horticulture*, 3, 6, <https://doi.org/10.48130/tih-2023-0006>
- DÖRING, T. F., BRANDT, M., JÜRGEN HEß, J., FINCKH, M. R., AND SAUCKE, H. (2005). Effects of straw mulch on soil nitrate dynamics, weeds, yield and soil erosion in organically grown potatoes. *Field Crops Research*, 94(2–3), 238–249, <https://doi.org/10.1016/j.fcr.2005.01.006>
- EL-SEMELLAWY, E. M. H., AND EL-KOUMY, H. M. (2015). Response of growth and yield of eggplants (*Solanum melongena* L.) to organic mulches and nitrogen fertilization levels during late summer season. *Egyptian Journal of Horticulture*, 42(2), 853–864, <https://doi.org/10.21608/ejoh.2015.1336>
- FAO. (2024). Food and Agriculture Organization of the United Nations. Retrieved December 25, 2024, from <http://www.fao.org/home/en/>
- FOLEY, J. A., RAMANKUTTY, N., BRAUMAN, K. A., CASSIDY, E. S., GERBER, J. S., JOHNSTON, M., MUELLER, N. D., O'CONNELL, C., RAY, D. K., WEST, P. C., BALZER, C., BENNETT, E. M., CARPENTER, S. R., HILL, J., MONFREDA, C., POLASKY, S., ROCKSTRÖM, J., SHEEHAN, J., SIEBERT, S., TILMAN, D., AND ZAKS, D. P. (2011). Solutions for a cultivated planet. *Nature*, 478, 337–342, <https://doi.org/10.1038/nature10452>
- FORCELLA, F., POPPE, S. R., HANSEN, N. C., HEAD, W. A., HOOVER, E., PROPSOM, F., AND MCKENSIE, J. (2003). Biological mulches for managing weeds in transplanted strawberry (*Fragaria* × *ananassa*). *Weed Technology*, 17(4), 782–787, <https://doi.org/10.1614/WT02-167>
- GENGER, R. K., ROUSE, D. I., AND CHARKOWSKI, A. O. (2018). Straw mulch increases potato yield and suppresses weeds in an organic production system. *Biological Agriculture and Horticulture*, 34(1), 53–69, <https://doi.org/10.1080/01448765.2017.1371077>
- GERTEN, D., HECK, V., JÄGERMEYR, J., BODIRSKY, B. L., FETZER, I., JALAVA, M., KUMMU, M., LUCHT, W., ROCKSTRÖM, J., SCHAPHOFF, S., AND SCHELLNHUBER, H. J. (2020). Feeding ten billion people is possible within four terrestrial planetary boundaries. *Nature Sustainability*, 3(3), 200–208, <https://doi.org/10.1038/s41893-019-0465-1>
- GILREATH, J. P., AND SANTOS, B. M. (2005). Weed management with oxyfluorfen and napropamide in mulched strawberry. *Weed Technology*, 19(2), 325–328, <https://doi.org/10.1614/WT-04-114r>
- GODFRAY, H. C. J., BEDDINGTON, J. R., CRUTE, I. R., HADDAD, L., LAWRENCE, D., MUIR, J. F., PRETTY, J., ROBINSON, S., THOMAS, S. M., AND TOULMIN, C. (2010). Food security: the challenge of feeding 9 billion people. *Science*, 327(5967), 812–818, <https://doi.org/10.1126/science.1185383>
- GÓMEZ DE BARREDA, D., BAUTISTA, I., CASTELL, V., AND LIDÓN, A. (2023). Rice straw mulch installation in a vineyard improves weed control and modifies soil characteristics. *Agronomy*, 13(12), 3068, <https://doi.org/10.3390/agronomy13123068>
- GRADILA, M., JALOBÁ, D., CIONTU, V. M., AND CRISTEA, R. M. (2023). Problem weeds control in strawberry crops in different growing systems in Romania. *Agriculture and Food*, 11, 296–303, <https://doi.org/10.62991/AF1996321943>
- GRASSBAUGH, E. M., REGNIER, E. E. AND BENNETT, M. A., (2004). Comparison of organic and inorganic mulches for Heirloom tomato production. *Acta Horticulturae* 638, 171–176, <https://doi.org/10.17660/ActaHortic.2004.638.22>
- GREENLY, K. M., AND RAKOW, D. A. (1995). The effect of wood mulch type and depth on weed and tree growth and certain soil parameters. *Arboriculture and Urban Forestry*, 21(5), 225–232, <https://doi.org/10.48044/jauf.1995.036>
- GÜRBÜZ, R., ALPTEKIN, H., AND KAYCI, H. (2021). Biçilmiş yabancı ot atıklarının patlıcan üretiminde malç materyali olarak kullanım olanağı. International Applied Sciences Congress, 14–15 April, Iğdır, Turkey, 40–48.
- GÜRBÜZ, R., ALMA, M. H., ALPTEKIN, H., AND TÜLEK, C. (2024). Performance of some organic mulch materials for weed suppression, soil conditions and yield in *Capsicum annuum* L. cultivation. *Journal of the Institute of Science and Technology*, 14(1), 18–38, <https://doi.org/10.21597/jist.1326729>
- HAMMERMEISTER, A. M. (2016). Organic weed management in perennial fruits. *Scientia Horticulturae*, 208, 28–42, <https://doi.org/10.1016/j.scienta.2016.02.004>
- HAAPALA, T., PALONEN, P., KORPELA, A., AND AHOKAS, J. (2014). Feasibility of paper mulches in crop production – a review. *Agricultural and Food Science*, 23(1), 60–79, <https://doi.org/10.23986/afsci.8542>
- HASHIMI, R., KOMATSUZAKI, M., MINETA, T., KANEDA, S., AND KANEKO, N. (2019). Potential for no-tillage and clipped-weed mulching to improve soil quality and yield in organic eggplant production. *Biological Agriculture and Horticulture*, 35(3), 158–171, <https://doi.org/10.1080/01448765.2019.1577757>
- HULME, M. F., VICKERY, J. A., GREEN, R. E., PHALAN, B., CHAMBERLAIN, D. E., POMEROY, D. E., NALWANGA, D., MUSHABE, D., KATEBAKA, R., BOLWIG, S., AND ATKINSON, P. W. (2013). Conserving the birds of Uganda's banana-coffee arc: land sparing and land sharing compared. *PloS One*, 8(2), e54597, <https://doi.org/10.1371/journal.pone.0054597>
- HUSSAIN, M., ABBAS SHAH, S. N., NAEEM, M., FAROOQ, S., JABRAN, K., AND ALFARRAJ, S. (2022). Impact of different mulching treatments on weed flora and

- productivity of maize (*Zea mays* L.) and sunflower (*Helianthus annuus* L.). *PloS One*, 17(4), e0266756, <https://doi.org/10.1371/journal.pone.0266756>
- IBM. (2011). IBM SPSS software. Retrieved from <https://www.ibm.com/products/spss>.
- IHTISHAM, M., HASANUZZAMAN, M., EL-SAPPAH, A. H., ZAMAN, F., KHAN, N., RAZA, A., AND ZHAO, X. (2023). Primary plant nutrients modulate the reactive oxygen species metabolism and mitigate the impact of cold stress in overseeded perennial ryegrass. *Frontiers in Plant Science*, 14, 1149832, <https://doi.org/10.3389/fpls.2023.1149832>
- IQBAL, R., RAZA, M. A. S., VALIPOUR, M., SALEEM, M. F., ZAHEER, M. S., AHMAD, S., TOLEIKIENE, M., HAIDER, I., ASLAM, M. U., AND NAZAR, M. A. (2020). Potential agricultural and environmental benefits of mulches – a review. *Bulletin of the National Research Centre*, 44, 1–16, <https://doi.org/10.1186/s42269-020-00290-3>
- JABŁOŃSKA-TRYPUĆ, A., WYDRO, U., WOLEJKO, E., AND BUTAREWICZ, A. (2019). Toxicological effects of traumatic acid and selected herbicides on human breast cancer cells: *in vitro* cytotoxicity assessment of analysed compounds. *Molecules*, 24(9), 1710, <https://doi.org/10.3390/molecules24091710>
- JABRAN, K. (2019). *Role of mulching in pest management and agricultural sustainability*. Cham, Switzerland: Springer Cham, <https://doi.org/10.1007/978-3-030-22301-4>
- JODAUGIENĖ, D., PUPALIENĖ, R., AND URBONIENĖ, M. (2006). Effect of different organic mulches on annual and perennial weed emergence. *Vagos* 71, 27–32.
- KASIRAJAN, S., AND NGOUAJIO, M. (2012). Polyethylene and biodegradable mulches for agricultural applications: a review. *Agronomy for Sustainable Development*, 32, 501–529, <https://doi.org/10.1007/s13593-011-0068-3>
- KAYA, Y. (2011). *Effect of green fertilizing and mulching on plant weeds and tomato yield in tomato* (p. 54). MSc thesis. Tokat, Turkey: Gaziosmanpaşa University, Graduate School of Natural and Applied Science, Department of Plant Protection.
- KITIŞ, Y. E. 2020. Buğday Tarımı-Yabancı Otlar ve Mücadelesi. Tarım Gündem Dergisi Özel Yayını. In T. Akar (Ed.), *Buğday Tarımı* (pp. 90–109). Izmir, Turkey: Nobel Akademik Yayıncılık, ISBN: 978-625-402-073-5.
- KOSTERNA, E. (2014). The effect of different types of straw mulches on weed-control in vegetables cultivation. *Journal of Ecological Engineering*, 15(4), 109–117, <https://doi.org/10.12911/22998993.1125465>
- LOPES, W. D. A., NEGREIROS, M. Z. D., DOMBROSKI, J. L. D., RODRIGUES, G. S. D. O., SOARES, A. M., AND ARAÚJO, A. D. P. (2011). Análise do crescimento de tomate ‘SM-16’ cultivado sob diferentes coberturas de solo. *Horticultura Brasileira*, 29, 554–561, <https://doi.org/10.1590/s0102-05362011000400019>
- MARBLE, S. C., STEED, S. T., SAHA, D., AND KHAMARE, Y. (2019). On-farm evaluations of wood-derived, waste paper, and plastic mulch materials for weed control in Florida container nurseries. *HortTechnology*, 29(6), 866–873, <https://doi.org/10.21273/horttech04437-19>
- MARQUES, L. J. P., BIANCO, M. S., BIANCO, S., CERVEIRA, W. R. JR., AND CARVALHO, L. B. (2019). Weed interference on the accumulation of dry mass and macronutrients of eggplant ‘Nápoli’. *Planta Daninha*, 37, e019191886, <https://doi.org/10.1590/s0100-83582019370100101>
- MARQUES, L. J. P., BIANCO, S., CECÍLIO, A. B., BIANCO, M. S., AND LOPES, G. D. S. (2017). Weed interference in eggplant crops. *Revista Caatinga*, 30(4), 866–875, <https://doi.org/10.1590/1983-21252017v30n406rc>
- MEMON, S. A., HOU, X., AND WANG, L. (2017). Morphological and physiological response of eggplant (*Solanum melongena* L.) to polyethylene and biodegradable mulches. *International Journal of Agriculture and Biology*, 19(3), 521–528, <https://doi.org/10.17957/IJAB/15.0316>
- MS. (2024). *Meteorological service*. Retrieved April 04, 2024, from <https://www.mgm.gov.tr/>
- NEAL, J. C., WOLFE, J. C., AND HARLOW, C. D. (2015). Auxinic herbicide phytotoxicity to container-grown *Muhlenbergia capillaris* and *Miscanthus sinensis*. *Journal of Environmental Horticulture*, 33(1), 1–6, <https://doi.org/10.24266/0738-2898-33.1.1>
- NYASAPOH, J. B. A., DANSO, E. O., KPODO, D. S., AMPONSAH, W., ARTHUR, E., SABI, E. B., OBOUR, P. B., AKORTEY, W., MENSAH, B. K. B., AYAYI, G. E., AND ANDERSEN, M. N. (2024). Irrigation and oil palm empty fruit bunch mulch enhance eggplant growth, radiation interception and dry matter yield. *European Journal of Agronomy*, 160, 127322, <https://doi.org/10.1016/j.eja.2024.127322>
- ODUM, P. (Ed.). (1971). *Fundamentals of ecology*. Eastbourne, USA: WB Saunders Company.
- OMIDVAR, N., OGBOURNE, S. M., XU, Z., BURTON, J., FORD, R., SALEHIN, B., AND BAI, S. H. (2023). Effects of herbicides and mulch on the soil carbon, nitrogen, and microbial composition of two revegetated riparian zones over 3 years. *Journal of Soils and Sediments*, 23, 2766–2782, <https://doi.org/10.1007/s11368-023-03530-x>
- PIRBONEH, H., GHASEMI, M., ABDZAD GOHARI, A., BAHARI, B. AND BABAEI BAZKIYAEI, Z., (2012). Effect of irrigation and straw mulch on yield and yield components of eggplant (*Solanum melongena* L.). *International Journal of Basic and Applied Sciences*, 3(1), 46–51.
- RAY, D. K., MUELLER, N. D., WEST, P. C., AND FOLEY, J. A. (2013). Yield trends are insufficient to double global crop production by 2050. *PloS One*, 8(6), e66428, <https://doi.org/10.1371/journal.pone.0066428>
- SABATINO, L., IAPICHINO, G., VETRANO, F., MONCADA, A., MICELI, A., DE PASQUALE, C., D’ANNA, F., AND GIURGIULESCU, L. (2018). Effects of polyethylene and biodegradable starch-based mulching films on eggplant production in a Mediterranean area. *Carpathian Journal of Food Science and Technology*, 10(3), 81–89.

- SARDANA, V., MAHAJAN, G., JABRAN, K., AND CHAUHAN, B. S. (2017). Role of competition in managing weeds: an introduction to the special issue. *Crop Protection*, 95, 1–7, <https://doi.org/10.1016/j.cropro.2016.09.011>
- STEINMETZ, Z., WOLLMANN, C., SCHAEFER, M., BUCHMANN, C., DAVID, J., TRÖGER, J., MUÑOZ, K., AND SCHAUMANN, G. E. (2016). Plastic mulching in agriculture. Trading short-term agronomic benefits for long-term soil degradation? *Science of the Total Environment*, 550, 690–705, <https://doi.org/10.1016/j.scitotenv.2016.01.153>
- SWANTON, C. J., NKOA, R., AND BLACKSHAW, R. E. (2015). Experimental methods for crop-weed competition studies. *Weed Science*, 63(1), 2–11, <https://doi.org/10.1614/ws-d-13-00062.1>
- SYED SHAHNAZ, S. M. N. A. (2023). Determination of physicochemical properties of soil before and after agricultural mulching process at MMP Fresh Farm, Kedah (Eggplant Farm Area) (p. 20). Bachelor's Degree in Chemical Engineering. Malaysia: Universiti Teknologi MARA.
- TAHER, D., SOLBERG, S. Ø, PROHENS, J., CHOU, Y. Y., RAKHA, M., AND WU, T. H. (2017). World vegetable center eggplant collection: origin, composition, seed dissemination and utilization in breeding. *Frontiers in Plant Science*, 8, 1484, <https://doi.org/10.3389/fpls.2017.01484>
- TARARA, J. M. (2000). Microclimate modification with plastic mulch. *HortScience*, 35(2), 169–180, <https://doi.org/10.21273/hortsci.35.2.169>
- TARRANT, A. R., BRAINARD, D. C., TIEMANN, L. K., AND HAYDEN, Z. D. (2024). Weed control, soil health, and yield tradeoffs of between-bed management strategies in organic plasticulture vegetable production. *Frontiers in Sustainable Food Systems*, 8, 1276415, <https://doi.org/10.3389/fsufs.2024.1276415>
- TEPE, I. (Ed.). (2022). Türkiye'de tarım ve tarım dışı alanlarda sorun olan yabancı otlar ve mücadeleleri. Van, Turkey: Yüzüncü Yıl University Press.
- TUIK. (2024). *Turkish Statistical Institute*. Retrieved December 12, 2025, from <https://www.tuik.gov.tr/>
- TÜLEK, C., GÜRBÜZ, R., AND ALPTEKİN, H. (2022). Organik malç materyallerinin domates (*Solanum lycopersicum* L.)'te yabancı ot kontrolüne etkisi. *Journal of Agriculture*, 5(2), 86–101, <https://doi.org/10.46876/ja.1208575>
- USANMAZ BOZHÜYÜK, A., GÜRBÜZ, R., ALPTEKİN, H., AND KAYCI, H. (2022). The use of different waste mulch materials against weeds which are problems in tomato (*Solanum lycopersicum* L.) cultivation. *Selcuk Journal of Agriculture and Food Sciences*, 36(2), 226–232, <https://doi.org/10.15316/sjafs.2022.029>
- ÜSTÜNER, T., AND GÜNCAN, A. (2002). Niğde ve yöresi patates tarlalarında sorun olan yabancı otların yoğunluğu ve önemi ile topluluk oluşturmaları üzerine araştırmalar. *Türkiye Herboloji Dergisi*, 5(2), 30–42.
- VAN DONK, S. J., LINDGREN, D. T., SCHAAF, D. M., PETERSEN, J. L., AND TARKALSON, D. D. (2012). Wood chip mulch thickness effects on soil water, soil temperature, weed growth and landscape plant growth. *Journal of Applied Horticulture*, 13(2), 91–95, <https://doi.org/10.37855/jah.2011.v13i02.22>
- YU, J., BOYD, N. S., AND GUAN, Z. (2018). Relay-cropping and fallow programs for strawberry-based production system: Effects on crop productivity and weed control. *HortScience*, 53(4), 445–450, <https://doi.org/10.21273/hortsci.12658-17>
- ZARGAR, M., MAGOMEDOVA, D., KURBANOV, S., PLESKACHIOV, Y., AND PAKINA, E. (2022). Macronutrient applications and irrigation regimes impact weed dynamics and weed seedbank augmentation in *Solanum melongena* L. fields. *Agriculture*, 13(1), 22, <https://doi.org/10.3390/agriculture13010022>

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