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ENHANCING FRUIT YIELD AND QUALITY IN PEPPER AND EGGPLANT: THE ROLE OF MULCHING TECHNIQUES

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Abstract

Soil mulching can create a microclimate at the plant level and has several advantages, the most important being its inhibitory effect on weed growth and its ability to retain soil moisture for a longer period. The purpose of this study is to determine the influence of different types of agricultural mulching films on yield and fruit quality of round pepper and eggplant. The experiment took place at RDIVFG Vidra in 2024. The biological material for peppers consisted of seedlings of the round pepper cultivar Asteroid 204 and eggplant cultivar Belona. Four variants were studied: unmulched soil, mulching with black foil, mulching with white-black foil, and mulching with brown foil. It was found that the use of mulch has beneficial effects on the yield and quality of fruits both in pepper and eggplant. Among the mulching options, the white-black foil resulted in the greatest increases in the number of fruits per plant, yield, and fruit weight in peppers, also positively influencing fruit quality. In eggplant, the greatest positive effects were observed with the use of brown foil.

Key words*: Capsicum annuum, fruit quality, mulch, Solanum melongena, yield.*

INTRODUCTION

In Romania, it has been observed that drought is not a constant and uniform phenomenon throughout the country. Rather, some areas are more exposed to the risk of drought during the hottest summer months. The areas most affected by drought stress are the southern and northeastern regions of the country, with the west also exposed, although with lower probability (Dobri et al., 2021).

Soil mulching is a maintenance practice often employed in vegetable crop, both in protected environments and in open fields. This practice involves covering the soil surface between plants with organic or synthetic materials (Choudhary et al., 2022; Ciofu et al., 2004; Dinu, 2022), leading to a specific microclimate around the plants that differs from that characteristic of unmulched soil (Tarara, 2000).

The main effects of mulching are reflected in the properties of the soil: it retains soil moisture for a longer period, serves as an effective method for controlling weeds, and helps maintain soil temperature (Choudhary et al., 2022; Ranjan et al., 2017). Due to its direct effect on soil moisture conservation by preventing water evaporation, mulching is widely used in arid regions (Kazemi and Safari, 2018). Additionally, some studies have indicated that the practice of covering land surfaces with mulch and utilizing drip irrigation can enhance the efficiency of nitrogen use by plants (Vázquez et al., 2006).

Soil mulching significantly influences the incidence and transmission of soil-borne diseases (Choudhary et al., 2022), suppressing the development of some diseases while favoring the spread of others (Ngosong et al., 2019).

Moreover, mulch affects the spectrum of reflected light (Kaul and Kasperbauer, 1992). Another important aspect is the potential of mulch in the biocontrol of certain vegetable pests (Choudhary et al., 2022; Ngosong et al., 2019).

Mulch positively influences earlier fruiting of vegetables and can improve fruit quality and yield (Choudhary et al., 2022).

Among synthetic materials, plastic films are the most widely used, which can come in various colors: black, white, gray (Dinu, 2022), brown, green (Johnson and Fennimore, 2005), yellow, red, blue (Manzoor et al., 2023) or combinations of two colors, such as black on one side (toward the ground) and red or another

silver color on the other side (Barche et al., 2015). Different colored mulches have specific effects on the microclimate created and, therefore, different influences on fruit production and quality (Choudhary et al., 2022; Manzoor et al., 2023; Mutetwa and Mtaita, 2014; Tarara, 2000).

One of the most commonly used types of plastic mulch is black (Amare and Desta, 2021; Lalitha et al, 2010), which increases soil temperature by transferring energy absorbed from the environment (Strik et al., 2017; Tarara, 2000). This increase in temperature affects not only the physical and chemical properties of the soil but also its pH level, thereby influencing the availability of essential nutrients for plant growth (Strik et al., 2019).

White mulch can produce the opposite effect of black mulch (Amare and Desta, 2021; Tarara, 2000). In the case of black-and-white mulch, the upper (white) layer is designed to reflect sunlight, helping to prevent soil overheating during periods of high temperatures, while the lower (black) layer effectively controls weeds due to its ability to absorb heat (Granatstein & Sanchez, 2009). Furthermore, transparent mulch, despite its limited ability to absorb solar radiation, is less effective for weed suppression (Zhang et al., 2021).

Regarding certain soil diseases, a positive effect has been observed in terms of decreasing their incidence when using black film mulching (Abdallah et al., 2019).

The aim of this study was to investigate the influence of various types of plastic mulch films on the production and quality parameters of round pepper and eggplant fruits.

MATERIALS AND METHODS

The experiment took place in an unprotected field located within the Research and Development Institute for Vegetable and Flower Growing Vidra, Ilfov County, in the south of Romania (44°16'22.5"N 26°10'11.7"E), between May - October 2024.

The biological material consisted of seedlings of round pepper cultivar Asteroid 204 and the eggplant cultivar Belona, two varieties of which the institute is the author and maintainer. Seedlings were produced in alveolar trays with a volume of 50 ml, in fertilized peat substrate with a pH of 5.5-6.5 (Klasmann TS3 product).

Three different types of mulch films were compared with each other and with the unmulched variant. The types of plastic mulch film studied in the present experiment were the following: black, white-black and brown mulch film. The field was prepared prior to planting by applying the plastic mulch film, according to the experimental variants, which were placed in split-plot design. Each variant had four repetitions, resulting a number of 16 experimental plots, with a surface area of 13 m^2 each.

The planting was carried out on 17th of May, 2024. The seedling was 60 days old, in both species.

The seedlings were planted in two rows on each bed, with a distance of 70 cm between rows. The distance between plants was 25 cm, for round pepper seedlings, and 40 cm for eggplant. The plants were watered by drip irrigation.

During the growing season, two manual and two mechanical weedings were carried out.

Table 1 presents the climatic conditions in which the research was carried out.

According to a press release issued by the National Meteorological Administration of Romania (2025), the year 2024 was the warmest year in the history of meteorological measurements in the country, and the summer of 2024 was the warmest in the period 1900-2024.

In the conditions of such a year, it is necessary to adapt crop technologies to current climatic conditions.

Irrigation was carried out in the same way for all variants, without considering the presence or absence of mulch. Watering was carried out 3 days apart, except for rainy days, with a watering rate of 55 m^3/ha. In periods with temperatures exceeding 32OC, watering was carried out with a rate of 65-70 m^3/ha.

The round pepper fruit was harvested at technological maturity, which coincides with physiological maturity. The technological maturity of eggplant differs from physiological maturity. Due to the strong influence of the mulched variants compared to the unmulched one, harvesting was differentiated, depending on the time at which each variant reached

technological maturity. Diseased or blossom end rot affected fruits were removed. As production indices, were determined the yield, the fruit weight and number of fruits per plant. Several analyses were carried out in the laboratory regarding the quality of round pepper and eggplant fruits. It was determined total of water content in fruit, total dry matter content, total dry soluble substance content, ash content. For each experimental variant, each determination was performed three times. The water and dry matter content of the fruit pulp was expressed in percentages. The gravimetric method was used to determine the water and dry matter content. For this purpose, 10 g of sample were dried in an oven at a temperature of 105°C until constant weight was reached (Krełowska-Kułas, 1993). Total soluble solids content (TSS) was determined with an Abbé refractometer and was expressed as °Brix (PN-90/A-75101/02).

The ash content was determined by calcining the samples at a temperature of 450°C, for 48 hours and was expressed as a percentage of fresh weight (% FW) (Horwitz, 2000).

The influence of experimental factors was analyzed using IBM SPSS Statistics for Windows, Version 26. The significance of differences between variants was evaluated using the Duncan's Multiple Range Test performed at $P \leq 0.05$.

Table 1. Crop climatic conditions (Vidra, Ilfov County, Romania, 2024)

		Temperature (^{O}C)			Relative air humidity (%)			
		Medium	Max	Min	Medium	Max	Min	Rainfall (mm)
May	I	16.05	22.2	10	60.1	89	32.9	8
	II	14.9	20.6	8.7	58.1	89.6	30.2	6
	III	18.58	25.55	12	56.45	86.09	26.55	6
June	I	24.72	32.4	16.6	52.5	90	23.8	4
	II	25.34	32	18.4	52.8	84.9	26.4	12
	III	25.02	31.64	19.09	56.91	88.27	27.36	42
July	I	26.44	33.2	19.1	42.8	76.1	21	24
	II	30.43	37.9	22	37.9	74.1	15.4	11
	III	25.02	31.64	19.09	56.91	88.27	27.36	42
August	I	25.98	31.5	17.6	53.1	86.4	27.2	0
	II	28.05	35	20.6	39.3	65.3	18.9	0
	III	25.83	33	19.55	41.45	68.36	19.73	0
September	I	23.13	30.2	15.9	42.1	72	20.5	0
	II	17.8	22.8	13.4	70.5	94.2	41.7	6
	III	19.24	26.4	13.1	61.8	91.4	30.2	40
October	I	16.04	23.4	10.5	74.3	99.4	39.7	10
	II	11.97	18.1	7.1	68.9	92.6	39.4	3
	III	10.58	19.27	3.82	70.73	98.36	33.27	0

RESULTS AND DISCUSSIONS

Figure 1 shows how the experimental variants influenced the phenological development stages at round pepper plants. In round pepper, technological maturity coincides with physiological maturity. The fruits were harvested at physiological maturity (BBCH85 and BBCH88).

The developmental stages of pepper plants were strongly influenced by the mulched variants, compared to the unmulched variant.

In round peppers, the first flower opened (BBCH 61) between 5th-10th of June, in the case of mulched variants. The unmulched variant led to a delay of 13.5-17.25 days. The significant differences are due to the fact that in the case of the variant without mulch, water was lost from the soil more quickly through evaporation, and the plants developed slowly.

Also, the variant without mulch led to delayed in fruit setting and ripening. The discrepancy between the no-mulch and mulched variants became even greater over time.

First fruit has reached typical size (BBCH 71) with a significant delay of 12-16.75 days in the case of the variant without mulch.

The beginning of fruit ripening (BBCH81-BBCH88) was significantly delayed in the no-mulch variant, even by a month compared to the variant in which black mulching film was used.

The very large differences between the unmulched and the mulched variant had several causes. The very high temperatures in the summer of 2024 led to faster evaporation of water from soil in the case of the variant

without mulch, and the amounts of precipitation and the watering norms applied were not sufficient for an optimal supply of water to the plant. It is known that pepper is a plant with high requirements for soil water content (Munteanu, 2003). Table 1 shows that during June-July, maximum temperatures were very high, which led to the loss of a large number of flowers. In addition, the lack of water caused by the pedological drought led to an inadequate supply of nutrients to plants, which contributed to the delay in fruit growth and ripening.

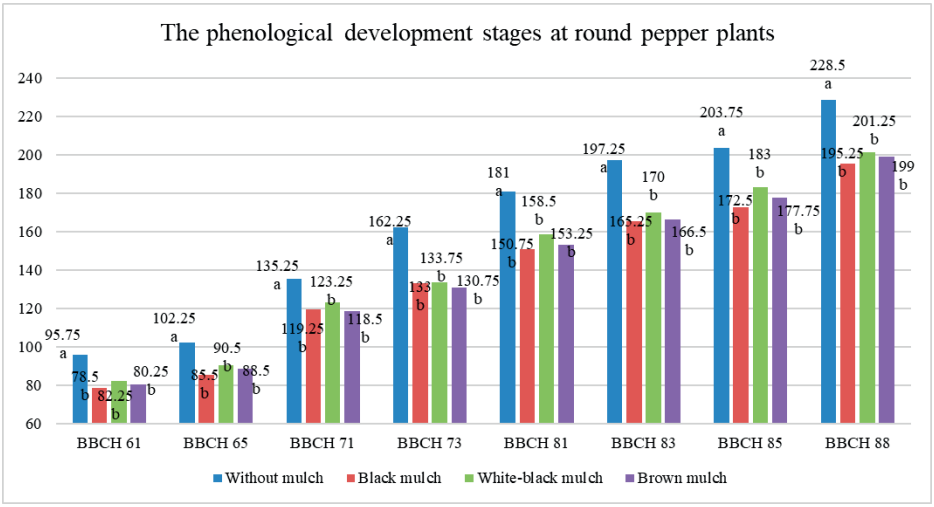

Figure 1. The influence of experimental variants the phenological development stages at round pepper

Even though Asteroid 204 is a variety with good tolerance to abiotic stress factors (Sbîrciog et al., 2016), the phenological development stages were longer due to climatic conditions, and therefore, plant development was slower. Basically, when in some mulched variants the round pepper plants were in the BBCH 85-88 development stage, the unmulched variant was still in the BBCH 73 development stage (Figure 2).

Figure 2. Round pepper plants on white-black mulching film (left) and on unmulched ground (right), 24th September

Due to the large differences in fruit ripening, three harvests were made for the mulched variants, and just two harvests for the unmulched variant. Round pepper fruits were harvested on 5th September, 19th September and 3rd October for the mulched variants, and on 19th September and 3rd October, for the variant without mulch.

In Figure 3 it can be seen which was the influence of the experimental variants on the phenological development stages at eggplant.

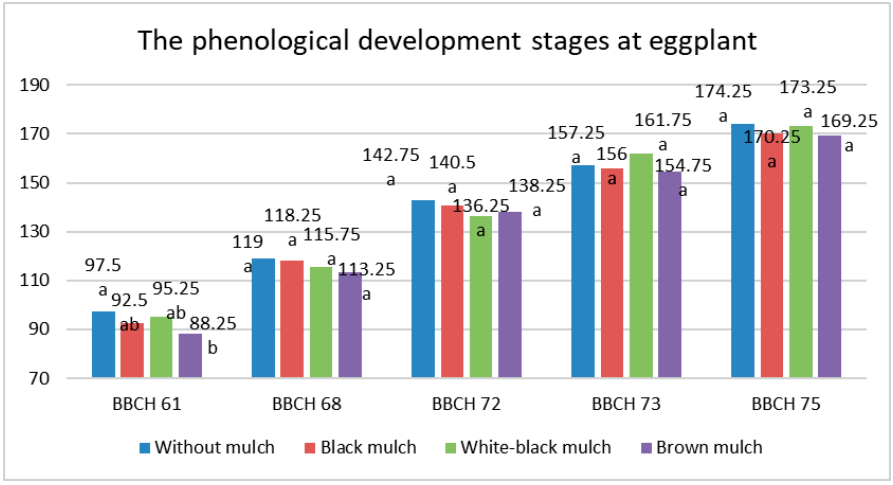

Figure 3. The influence of experimental variants the phenological development stages at eggplant

In general, eggplant is a specie that tolerates better then pepper drought and heat stress. The variety taken into the research tolerated the climatic conditions well and there were no significant differences between phenological development stages even in the case of the variant without mulch.

At eggplant, flowering took place between 14th-24th June. The brown mulch film showed a significant precocity of 9.25 days compared to the version without mulch. Even though the version without foil was much less productive, were not other delays in phenological development stages in eggplant. Fruit setting took place, without significant differences, between 15th-30th July and fruit has reached typical size and form 5th-10th August. Three harvests were carried out at 10-day intervals, starting on 5th August.

Table 2 presents the influence of experimental variants on quantity and weight of fruit, in round pepper and eggplant.

At round pepper, the number of fruits per plant was strongly influenced by the experimental variants. All mulched variants led to significant differences compared to the unmulched variant, but there were also significant differences between the mulching variants.

Table 2. The performance of peppers and eggplants under different types of mulching

Round pepper			
	Fruits per plant	Fruit weight (g)	Yield (t/ha)
Without mulch	4.18±0.23 c	135.13±12.04 a	33.88±4.13 b
Black mulch	5.09±0.15 b	151.95±19.94 a	46.55±7.27 a
White-black mulch	5.87±0.60 a	146.08±12.07 a	51.71±9.46 a
Brown mulch	5.17±0.35 b	145.95±2.18 a	45.27±3.61 a
Eggplant			
	Fruits per plant	Fruit weight (g)	Yield
Without mulch	4.53±0.43 b	210.99±30.01 b	33.10±2.02 b
Black mulch	5.00±0.35 ab	224.73±24.97 ab	39.38±5.60 ab
White-black mulch	4.93±0.41 ab	232.66±22.88 ab	40.14±5.02 ab
Brown mulch	5.19±0.32 a	251.24±12.45 a	45.65±4.52 a

*Duncan test: Mean values in a column that do not share the same letter (a, b, c) signify significant differences ($p \leq 0.05$).

The biggest number of fruits were obtained in the case of the variant in which white-blach mulching film was used, which differed significantly both from the variant without mulch, and also from the variants in which black mulching film and brown mulching film were used. The white-black mulching film led

to an average number of 5.87 fruits/plant. The black and brown mulching film led to an average number of 5.09-5.17 fruits/plant, significantly higher than the unmulched variant which produced an average of 4.18 fruits per plant.

However, the weight of round pepper fruits did not differ significantly.

The mulched variants led to significant increases of yield of round pepper, compared to the variant without mulch, but no significant differences were observed between them. The highest yield of round pepper was obtained in the case of the variant where white-black mulching film was used. The yield of 51.71 t/ha corresponds to a maximum potential of production of the Asteroid 204 variety (Sbîrciog et al., 2016). The brown and black mulching film led to a yield of 45.27-46.55 t/ha.

Basically, the plants invested water and nutrient resources in increasing the number of fruits per plant and in the fruit ripening process, but without a significant different in fruit weight.

In eggplant, the highest number of fruits per plant was obtained by using the brown mulching film. This variant led to an average number of 5.19 fruits/plant, significantly higher than the unmulched variant, which led to the formation of 4.53 fruits per plant. The other two variants also led to increases in the number of fruits compared to the variant without mulch, but the differences were insufficient to be significant.

Regarding the weight of eggplant fruits, it was significantly influenced by the variant mulched with brown film. This led to an average increase of 40.25 g compared to the variant without mulch. The increases in the case of the other two variants (black and white-blach mulching film) were insignificant.

The highest eggplant yield was obtained when the land was mulched with brown mulching film. This variant led to a yield of 45.65 t/ha, with a significant difference of 12.55 t/ha compared to the variant without mulch.

Although eggplants are known for their drought tolerance, their quality and yield can decrease under water deficit conditions. However, plant response to plastic mulch varies depending on the eggplant variety, materials used, and environmental conditions (Abdrabbo et al., 2017).

Table 3 presents the influence of experimental variants on some quality indices of round pepper and eggplant fruits.

Table 3. Comparative Analysis of Water Content, Dry Weight, Ash Content, and Total Soluble Solids in Round Pepper and Eggplant Under Different Mulching Treatments

Round pepper				
	Water (%)	DW (%)	Ash (% FW)	TSS (°Brix)
Without mulch	91.35±0.27 b	8.65±0.27 a	0.51±0.02 b	6.80±0.12 b
Black mulch	92.05±0.44 ab	7.95±0.44 ab	0.54±0.05 ab	7.30±0.27 a
White-black mulch	92.76±0.48 a	7.24±0.48 b	0.59±0.03 a	7.14±0.27 ab
Brown mulch	92.57±0.44 a	7.43±0.44 b	0.53±0.04 ab	7.17±0.26 ab
Eggplant				
	Water (%)	DW (%)	Ash (% FW)	TSS (°Brix)
Without mulch	90.80±0.60 b	9.20±0.60 a	0.66±0.10 ab	4.13±0.06 c
Black mulch	91.61±0.22 ab	8.39±0.22 ab	0.68±0.03 ab	4.54±0.27 b
White-black mulch	92.21±0.17 a	7.79±0.17 b	0.78±0.04 a	4.90±0.17 a
Brown mulch	92.30±0.63 a	7.70±0.63 b	0.59±0.04 b	4.52±0.07 b

*Duncan test: Mean values in a column that do not share the same letter (a, b, c) signify significant differences ($p \leq 0.05$).

The composition of the dry matter in fruits includes sugars, especially carbohydrates, of which glucose and fructose constitute approximately 48% of the total. In addition, lipids, proteins, minerals, vitamins, organic acids and phenolic compounds are found (Kader, 2002). In the experiment, the total dry matter was found to be highest in the variant without mulch. In contrast, all types of mulch demonstrated superior effectiveness in maintaining adequate plant hydration. Specifically, the use of black-and-white and brown foils yielded more favorable results in this regard compared to the black foil mulch for both species (Table 3). These findings align with the observations reported by Iqbal et al. (2015). Furthermore, the composition of dry matter can be influenced by various factors, including genotype, environmental conditions, cultivation practices, and available water levels (Gruda et al., 2025; Rouphael et al., 2012; Zhou et al., 2024).

The role of soluble solids, together with other phytochemicals, is essential in defining fruit aroma. The soluble solids influence the

refractive index of aqueous extracts of the fruit and among these can be included soluble sugars, soluble pectin, organic acids and various non-carbohydrate compounds (Diaconu, 2006). An analysis of the impact of mulching on the content of soluble solids is presented in Table 3. Compared to the control variant (without mulch), significant differences were observed between the type of black mulching film for round pepper and black-and-white mulching film for eggplant. Thus, for round pepper, the variant without mulch had the lowest values (4.13°Brix), while the black-and-white mulch recorded the highest values (4.90°Brix), significantly higher than the first variant. Mehraj et al. (2015) also mentioned a significantly higher influence of TSS content in plums under the influence of black polyethylene mulch. In eggplant, all types of mulch significantly influenced this quality parameter compared to unmulched soil. In this case, the highest values of this indicator were observed in black-and-white mulch (4.90°Brix) followed by black (4.54°Brix) and brown (4.52°Brix) mulch and the lowest in unmulched soil (4.13°Brix). This aspect is particularly important for fruits intended for industry, given that the profitability of the product is directly influenced by the content of soluble solids (Stevens, 1972).

The influence of soil mulching on physicochemical parameters was significant, with higher average values observed in mulched soil compared to bare soil, except for dry residue. This study suggests that plastic mulch can be an effective option for improving the quality and quantity of agricultural products. In conclusion, the use of plastic mulching can significantly improve crop yields in agriculture, especially in areas affected by moisture deficit.

The study of the effects of different types of mulching revealed that the fruits of the two species exhibited a slight increase in ash content, with significantly higher values in the presence of black-and-white mulching film compared to the no-mulch variant. The improvement of ash content was particularly observed under the influence of various types of green mulch, such as in the case of Aloe vera (Darini, 2019) or sweet potato (Kosterna, 2014). The literature shows that plastic mulch can contribute to improving the nutrient content in pepper plants (Gao et al., 2019).

When analyzing the effect of mulching practices on fruiting parameters and quality indicators in peppers, it is observed that different mulch films have a significant impact on yield per hectare and, consequently, on the number of fruits per plant (Table 4).

Table 4. Analysis of Pearson correlations between mulching practices and production characteristics or fruit quality indicators in round pepper

	Types of mulching	Fruits/ plant	Fruit weight (g)	Yield (t/ha)	Water (%)	DW (%)	TSS (°Brix)	Ash (% FW)
Types of mulching	1	0.613(*)	0.230	0.509(*)	0.457	-0.457	0.526	0.298
Fruits/ plant		1	0.508(*)	0.921(**)	0.579(*)	-0.579(*)	0.592(*)	0.624(*)
Fruit weight (g)			1	0.799(**)	0.099	-0.099	0.327	0.064
Yield (t/ha)				1	0.490	-0.490	0.600(*)	0.491
Water (%)					1	-1.000(**)	0.004	0.077
DW (%)						1	-0.004	-0.077
TSS (°Brix)							1	0.781(**)
Ash (% FW)								1

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

Additionally, an improvement in fruit hydration is noted in mulched plants; however, this relationship is not statistically significant. The relationship between fruit yield and their weight or the number of fruits per plant is positively correlated and statistically significant (r=0.799 and r=0.921, respectively). There is also a positive interdependent relationship, though of lesser intensity, between the number of fruits per plant and their weight, fruit water content, total soluble solids (TSS), and ash content, with correlation coefficients of

(r=0.508, r=0.579, r=0.592, and r=0.624, respectively). Furthermore, the correlation between TSS and ash content in fruits is positive and statistically significant (r=0.781).

Table 5 presents the influence of mulching practices on the production and quality indicators of eggplant fruits. The results obtained indicate a significant positive linear interdependence between mulching practices and the number of fruits per plant, as well as their weight (r=0.521, r=0.576). Additionally, there is a significant correlation between different types of mulch and yield, as well as the hydration of the biomass produced (r=0.726 and r=0.808, respectively). The correlation between the number of fruits per plant and crop yield is significant (r=0.667). The relationship between fruit weight and yield is of much higher intensity (r=0.835). The degree of correlation between the hydration status of the fruits and TSS is slightly lower (r=0.691), yet the correlation remains significant.

Table 5. Analysis of Pearson correlations between mulching practices and production characteristics or fruit quality indicators in eggplants

	Types of mulching	Fruits/ plant	Fruit weight (g)	Yield (t/ha)	Water (%)	DW (%)	TSS (°Brix)	Ash (% FW)
Types of mulching	1	0.521(*)	0.576(*)	0.726(**)	0.808(**)	-0.808(**)	0.567(*)	-0.175
Fruits/ plant		1	.149	0.667(**)	0.443	-0.443	0.421	-0.105
Fruit weight (g)			1	0.835(**)	0.195	-0.195	0.023	-0.230
Yield (t/ha)				1	0.369	-0.369	0.253	-0.197
Water (%)					1	-1.000(**)	0.691(*)	-0.114
DW (%)						1	-0.691(*)	0.114
TSS (°Brix)							1	0.430
Ash (% FW)								1

*. Correlation is significant at the 0.05 level (2-tailed).
*. Correlation is significant at the 0.01 level (2-tailed).

CONCLUSIONS

The use of plastic mulch significantly influenced the phenological development stages of round pepper, variety Asteroid 204, but the eggplant cultivar Belona did not show any differences in plant development.

The number of fruits per plant and the yield of round peppers was significantly influenced by all mulching variants, the highest values being obtained when mulching with black-and-white foil.

In eggplant, brown mulching film led to the highest values of the number of fruits per plant, fruit weight and yield.

The variants with white-black and brown mulching foil led to significant increases in fruit water content, both in round pepper and eggplant, meaning a better hydration of them.

The total soluble solids content in round peppers was positively influenced by the use of black mulching foil, and in eggplants, all mulching variants led to significant increases compared to the no-mulch variant.

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