Possibilities of Using Organic Wastes as a Growing Medium in Soilless Culture for Cut Flower Rose

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The possibilities of using organic wastes, such as hazelnut shells (HS), walnut shells (WS), hazelnut skins (HzS), and spent mushroom compost (SMC), as growth medium in cut flower rose cultivation in soilless substrate culture were investigated. The parameters, such as the date of cutting the flower (day), flower stem length (cm), flower stem diameter (mm), flower length (cm), flower diameter (cm), flower color, color of the top and bottom of the leaf, and yield (piece), were examined. In addition, samples taken from the growth medium at the beginning and ending stages of the experiment were analyzed. The first flowers were cut from the HzS +P medium 38 days after planting. The highest yield value (20.6 flower/plant) was obtained from SMC medium. The longest flowers (63.89 ± 0.947 cm) and the thickest stem flowers (5.86 ± 0.136 mm) were cut from the control medium. It was determined that the media also affected the flower and leaf colors. According to the results obtained, SMC and HzS+perlite mediums can be recommended as an alternative to cocopeat in the production of cut roses in soilless substrate culture.

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INTRODUCTION

Roses, which are among the most popular flowers in the world, are a woody perennial flowering plant of the genus *Rosa* in the Rosaceae family. According to the classification made by the American Rose Society, roses are divided into three classes as wild roses, old garden roses, and modern roses. Today, the most used roses as cut flowers are hybrid tea roses, which are among the modern roses. Flowers are single or double, with or without thorns. The rose types, which can be fragrant or odorless, can be upright bushes, climbing, or creeping forms. The Asian continent is accepted as the gene center of roses, which have more than 300 natural species and tens of thousands of cultural varieties (Gülbağ *et al*. 2021). It is known that the greatest species diversity of roses, which naturally occurs in temperate regions of North America, Europe, Asia, and the Middle East, is in western China (Khandaker *et al*. 2020). Roses, whose first cultivation is thought to have started in China 5000 years ago, are now grown for purposes such as cut flowers, pot and garden plants, perfumery, cosmetics, food, and medicinal plants (Shaafi *et al*. 2022). According to 2019 data, the foreign trade volume of roses, which has a high economic value in the international market, is 7,207,032,000 dollars. Of this, 95.98% was cut roses and 4.02% was garden roses (Gülbağ *et al*. 2021). Roses used as cut flowers can be grown in greenhouses with or without soil.

Because roses stay in the same area for a long time, the soil gets tired and weakened, and soil-borne diseases and pests can reach dense populations in the soil over time. This causes a decrease in the yield and quality of roses. Soilless culture in rose cultivation can be a solution to these problems. Soilless farming is a method of growing plants in any organic or inorganic media without using soil, in which the water and nutrients needed by the plant are given directly to the growing media (Hazar and Baktır 2014). Although soilless culture systems have high initial investment costs, they are becoming more common daily because of their advantages, such as higher quality and stable yield, lower disease risk, and accordingly lower pesticide use (Nurhidayati *et al*. 2021). The choice of growing media is a key factor in soilless systems (Feyzizadeh *et al*. 2023). Soilless culture is divided mainly into two groups as solid medium (substrate) culture and hydroponics culture. Solid media cultures also consist of two groups, organic and inorganic solid media. Organic or inorganic materials can be used as growing medium in soilless solid medium culture. While peat, coconut fiber (cocopeat), burnt rice husks, bark, *etc*. media are used as organic growing media; rockwool, glass wool, perlite, pumice stone, and volcanic tuff, *etc*., mediums can be used as inorganic growing media (Hazar and Baktır 2014).

In soilless culture, while focusing on obtaining the highest and best quality yield by applying all the methods of modern and technological agriculture, minimum input costs are of great importance. Cocopeat is a widely used substrate in soilless culture all over the world. However, in countries, such as Türkiye, that import the cocopeat from abroad, the input costs of using the cocopeat is quite high. Although soilless cut rose cultivation using cocopeat has achieved good results in terms of yield, there is a requirement to test alternative agriculturally sourced substrates that are cheaper and readily locally available to reduce input costs. Thus, in addition to reducing the input costs, it will be possible to bring the agricultural wastes, which are produced in large quantities because of agricultural production and whose usage areas are limited, to the economy and to reduce the negative effects of these wastes on the environment.

It is important to recycle organic waste. Two methods can be applied to reuse organic waste in agricultural activities. The first of these is to use the waste directly, as in cocopeat, and the second is to use it by composting. Organic waste can be converted into a nutrient-rich biofertilizer by composting (Wang *et al*. 2022). In the current research, organic wastes were used directly without being subjected to any composting process.

Agricultural organic wastes, such as hazelnut shells (HS), walnut shells (WS), hazelnut skins (HzS), and spent mushroom compost (SMC), are available in large quantities in Türkiye. Among them, hazelnut shells and walnut shells are used as fuel in Türkiye. The waste compost that comes out after the mushroom is grown and the hazelnut skins (pericarp), which are a brown texture under the hazelnut hard shell (endocap), have no economic use. Hazelnut skins are sometimes used in the animal feed industry or randomly poured into gardens (Şahin *et al*. 2019; Umor *et al*. 2021). However, a private entrepreneur has submitted an application for the patent of the compost obtained from this product. This product has not yet become widespread, and the necessary academic studies have not been completed (Turkish Patent and Trademark Office 2023).

This study was conducted to evaluate the possibility of using agricultural wastes, such as walnut shells, hazelnut shells, hazelnut skins, and spent mushroom compost, as alternative growing mediums in soilless rose cultivation. These resources are locally abundant in Türkiye and have limited usage areas. In addition, the effects of these wastes on the yield and quality characteristics of roses grown in soilless culture were determined and compared with roses grown on cocopeat, an imported growing medium.

EXPERIMENTAL

Materials

The study was completed in fully controlled R&D greenhouses in Kırşehir Ahi Evran University Faculty of Agriculture. Grafted saplings of the *Rosa* cv. 'Samurai' obtained from a private company were used as plant material in the study.

Five different media, such as wastes used alone, cocopeat (control), spent mushroom compost (SMC), walnut shells (WS), hazelnut shells (HS), and hazelnut skins + perlite (HzS+P) (3:1) mixture were used as a growing media. In production, ready-made slab bags of 100 × 15 × 12 cm (18 L) dimensions were used.

Methods

Preparation of media

The HS and WS supplied from the factories were laid on the concrete floor and filled into plastic bags after rolling into small pieces by passing a roller over them. Waste mushroom compost (SMC) obtained from the mushroom production facility (Türktur Mushroom, Mucur, Kırşehir) was filled into plastic bags after being mixed with perlite at a 3:1 ratio, without undergoing any processing.

Set up and trial runs

Trials were established on 01.12.2020 and concluded on 04.12.2021. The saplings were planted in the growing media filled in ready-made slab bags with intra-row spacing × inter-row spacing at 50 cm × 140 cm. About 30 saplings were planted in each medium, and measurements and observations were taken from each plant separately. Irrigation was done for 2 min at the beginning of every hour with the nutrient solution in summer, and for 1 min at the beginning of every hour in winter months. Each medium was washed twice by giving just water in the beginning and middle of summer. In addition, the SMC medium was washed 2 more times. The solution prepared by modifying the model proposed by Hoagland and Arnon (1950) and adjusting according to the developmental status of the plants was used as the nutrient solution. The nutrient solution of pH 6 was given to the media. The EC was adjusted to initially 1.5 then to 2.5 (Hazar and Baktır 2014).

Examined parameters

In the study, parameters, such as the date of cutting the flower (day), flower stem length (cm), flower stem diameter (mm), flower length (cm), flower diameter (cm), flower color, color of the top and bottom of the leaf, and yield (piece) were examined. The cutting date of each flower in different environments were recorded. The flowers were cut from the bottom of the first or second five-part leaf when the calyx was opening, and the first two petals were beginning to open (Kazaz *et al*. 2010). The distance between the cut point and the tip of the petal was measured in cm. Flower stem diameters were measured in mm with a caliper from the bottom of the first five-part leaf from the top. Flower length measurements were obtained by measuring the distance between the sepals and the tips of the petals, and the flower diameters were obtained by measuring the distance between the tips of the petals. Flower and leaf color measurements were made with a Pantone handheld colorimeter (Pantone color CUE 2, Pantone LLC, Ashford, United Kingdom). Flower color measurements were made from the outer middle part of the outermost petal. Leaf measurements were made from the lower middle and upper middle parts of one of the middle leaflets of the first five-part leaf and recorded. The term Lab L^* represents the lightness coordinate (L^* = 0 indicates perfect black and L^* = 100 is perfect white), a^* is the red/green coordinate (+a^* indicates red, – a^* indicates green), and b^* is the yellow/blue coordinate (+b^* indicates yellow, and -b^* indicates blue) (Özcan 2008).

Medium analysis

The substrates were oven-dried at 60 °C for 48 h and ground to pass through a 1.0 mm sieve. Ash, moisture, and pH were determined by standard procedures (Kacar and İnal 2010). The carbon (C) content was calculated according to Tiquia and Tam (2000), and the Kjeldahl method was used to determine the total nitrogen (N) content of each substrate. The carbon/nitrogen (C:N) ratio of each substrate was then determined.

Statistical analysis

The statistical analyses were performed by SPSS Software Programme (IBM Corp., Armonk, NY, USA). The data were subjected to one-way analysis of variance. Comparisons of the means of the applications were done by using Duncan multiple comparison test.

RESULTS

The data obtained as a result of the research are given below.

Greenhouse temperature and humidity values

The temperature and humidity values inside the greenhouse were first recorded in December (2020) when the saplings were planted, and they were recorded regularly until the end of November (2021), when the experiment was terminated. Temperature and humidity values by month are shown in Table 1.

Table 1. Climate Values Inside the Greenhouse

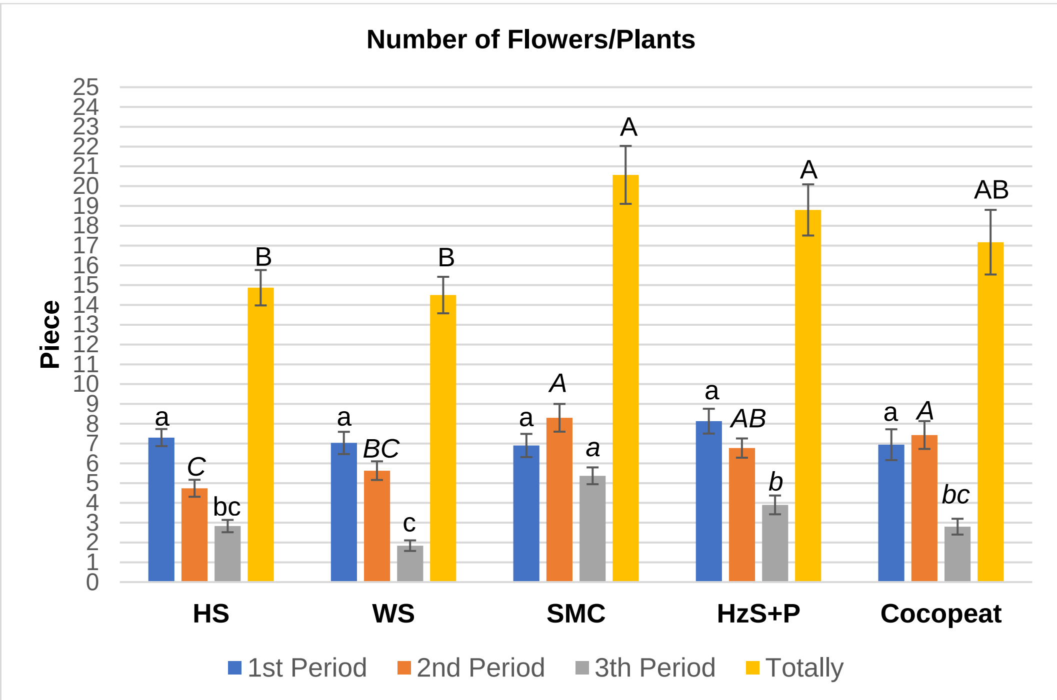
Season	Saplings Development		1. Period				2. Period			3. Period		
	12	1	2	3	4	5	6	7	8	9	10	11
Heat (°C)	15.32	17.79	16.93	15.05	18.39	20.67	20.91	23.88	23.43	19.82	15.87	15.66
Average (°C)	16.56		17.76				22.74			17.11		
Moisture (%)	54.49	48.97	55.72	60.25	65.51	55.90	66.26	52.80	64.73	67.44	61.71	67.34
Average Humidity (%)	51.73		59.35				61.26			65.49		

Number of cut flowers (Yield)

The first flowers were cut from the HzS + P (3:1) medium 38 days after the planting date. The latest flower cut was 74 days after planting in SMC medium (Table 2). In this study, the number of cut flowers was divided into three different periods (1st period: February-March-April-May, 2nd period: June-July-August, 3rd period September-October-November). Analyses were made according to these results by calculating the average number of cut flowers per plant (Table 2). When the effect of medium on yield was examined, the highest yield value (20.6 flowers/plants) was obtained from SMC media. This was followed by HzS (18.8 flowers/plant) and cocopeat (17.2 flowers/plants), respectively. When examined based on periods, the highest yield was obtained from HzS medium with 8.13 flowers/plants in the 1st period. This difference was not statistically significant. However, the highest yields (8.30 and 5.37 flowers/plants, respectively) in the 2nd and 3rd periods were obtained from SMC medium and the difference between them was statistically significant (Fig. 1).

Table 2. Planting and First Flower Cutting Dates

Environment	Sapling Planting Date	First Flower Cut Date	Time from Planting to the First Flower Cutting (Day)
HS	01.12.2020	07.02.2021	68
WS	01.12.2020	06.02.2021	67
SMC	01.12.2020	13.02.2021	74
HzS+P	01.12.2020	08.01.2021	38
Cocopeat	01.12.2020	07.02.2021	68



	1st Period	2nd Period	3rd Period	Totally
$F_{(4,145)}$	0.712	(4.145) = 0.175	(4.145) = 12.324	(4.145) = 4.094
Sig	0.585	0.00	0.00	0.004

Fig. 1. Number of flowers cut by periods (pieces/plant)

Flower quality parameters

While the difference between the substrates in terms of flower stem length (cm), flower stem diameter (mm), and flower length (mm) was statistically very significant ($p < 0.001$), the effect of substrates on flower diameter was statistically insignificant ($p > 0.05$)

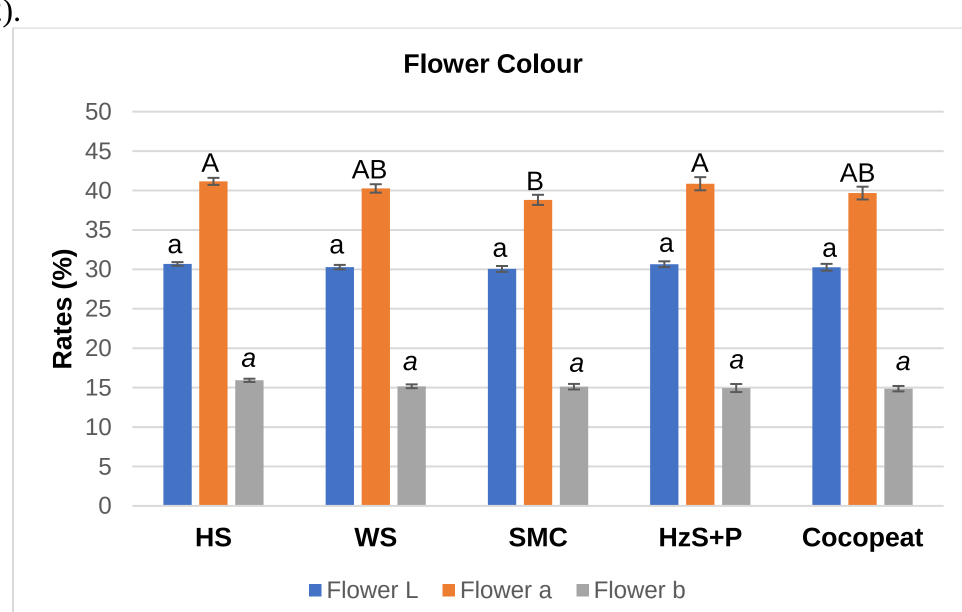
(Table 3). The longest stem flowers (63.89 ± 0.947 cm) were harvested from cocopeat medium, while the shortest flowers (56.51 ± 1.060 cm) were obtained from WS medium. Similarly, the thickest stemmed flowers (5.86 ± 0.136 mm) were obtained from the cocopeat medium, and the other four medium were statistically in the same group in terms of flower stem values. In terms of flower sizes, HzS+P medium gave the highest value (41.77 ± 0.565 mm), while the lowest values were obtained from SMC and cocopeat mediums.

Table 3. Results on Flower Quality

Mediums	Flower Stem Length (cm)	Flower Stem Diameter (mm)	Flower Bud Size (mm)	Flower Diameter (mm)
HS	56.54 ± 0.749 c	5.19 ± 0.099 b	41.58 ± 0.504 ab	29.54 ± 0.262 ab
WS	56.51 ± 1.060 c	5.34 ± 0.136 b	40.08 ± 0.607 bc	29.14 ± 0.334 ab
SMC	58.39 ± 1.633 bc	5.49 ± 0.115 b	39.38 ± 0.453 c	28.63 ± 0.371 b
HzS+P	60.36 ± 1.384 b	5.37 ± 0.088 b	41.77 ± 0.565 a	29.52 ± 0.291 ab
Cocopeat	63.89 ± 0.947 a	5.86 ± 0.136 a	38.62 ± 0.573 c	29.69 ± 0.335 a
$F_{(4,145)}$	6.684	4.642	6.355	1.775
Sig	0.000	0.001	0.000	0.137

Flower color

There was no statistically significant difference in *L** and *b** values of flowers harvested from different substrates ($p > 0.05$). Although there were differences in the a-value indicating the red color, these differences were not statistically significant ($p > 0.05$). The darkest red flowers were harvested from HS and HzS media (*a**: 41.2 and 40.9, respectively), while the lightest red flowers were harvested from SMC media (*a**: 38.8) (Fig. 2).

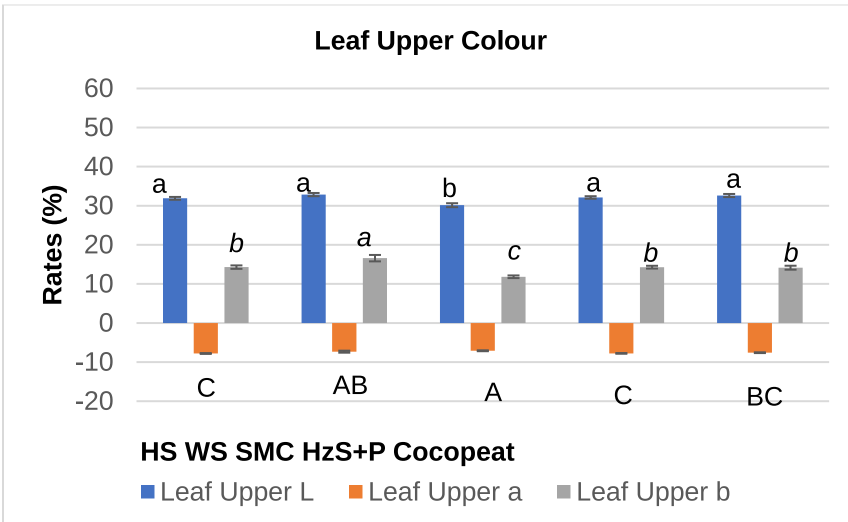


	L^*	a^*	b^*
$F_{(4.145)}$	0.618	1.971	1.485
Sig	0.65	0.102	0.21

Fig. 2. Effects of growing medium on flower colors

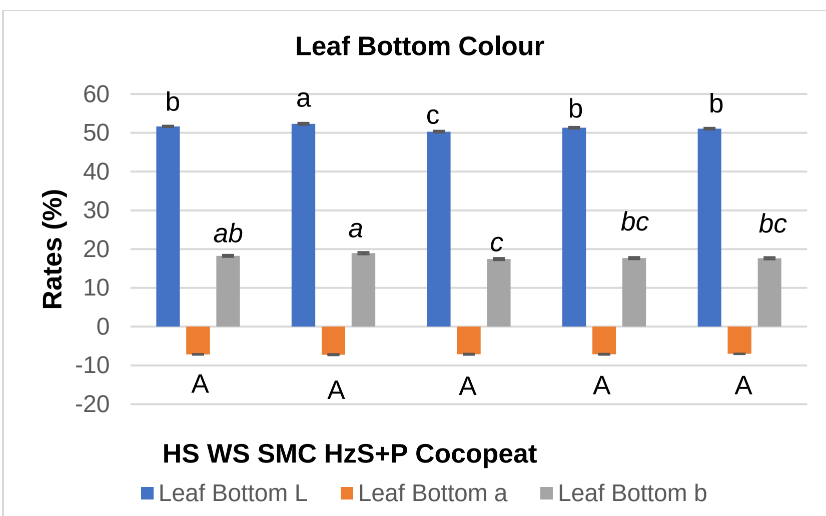
Leaf upper color

When the leaf top colors were examined in terms of *L** values, it was determined that the leaf top colors of the roses grown in SMC medium were darker (*L**:30.140) than the plants grown in other medium. Leaf top color *L** values of flowers grown in other medium were statistically included in the same group. When the results were examined in terms of *a** values, it was determined that the medium had a statistically significant effect on the leaf top colors. The value was -7.1 in SMC medium while it was -7.6 in cocopeat medium (Fig. 3).



	*L**	*a**	*b**
$F_{(4.145)}$	6.945	4.124	10.381
Sig	0.00	0.003	0.00

Fig. 3. Effects of growing medium on leaf upper colors



	*L**	*a**	*b**
$F_{(4.145)}$	12.18	0.505	5.426
Sig	0.00	0.732	0.00

Fig. 4. Effects of growing medium on leaf bottom color

Leaf bottom colour

When the leaf bottom color values were examined, it was determined that the effect of the growing medium on the L* and b* values was statistically significant, while the effect on the a* values was insignificant. While the medium with the lightest leaf bottom color (L*: 52.3) was obtained from the WS medium, the plants with the darkest leaf bottom color (L*: 50.3) were obtained from the SMC medium. In b* values, while the SMC medium was the closest to zero with a value of +17.4, the WS environment was determined as the value closer to yellow with a value of +18.9 (Fig. 4).

Medium analysis

The physicochemical properties of the organic wastes used as growth medium in the study at the initial and final stages are given in Table 4. When the pH values were examined at the beginning of the study, it was determined that all media had acidic characteristics, but the SMC media (6.68) was close to neutral. At the end of the research, it was determined that the pH values increased and averaged between 5.97 to 7.38. While all medium contained 0.83% to 47.6% ash in the initial phase, these percentages changed to 13.6% to 62.4% at the end of the research. While the lowest and highest values of N contents of the growing medium were determined as 0.35% (HS) and 1.68% (HzS+P) at the beginning stage, increases occurred in all medium except HzS+P media at the end of the experiment. It was determined that the medium with the highest organic carbon level was WS (57.5%) at the beginning of the experiment, and SMC (30.4%) was the lowest. The highest C:N ratio (164) was detected in the HS medium at the beginning of the research (Table 4).

DISCUSSION

In parallel with the developing technology and population growth, natural resources are rapidly depleting and the reuse of used materials for another purpose, (recycling) is gaining importance every day. In modern farming systems where soilless farming is applied, mainly considerations such as cost, performance, and uniformity, are considered when choosing a growing medium (Raviv 2013). A quality growing medium is vitally important for obtaining quality flowers. The need for quality and high performance standard growing medium that can compete in international markets continues today (Majid *et al*. 2017). Therefore, it is important to create new growth medium and to offer alternative medium to the sector, especially if these mediums consist of organic wastes.

It has been reported that ideal temperatures for growing cut flower roses should be between 16 and 24 °C on average, and the relative humidity in the greenhouse should be between 60% and 80% (Hazar and Baktır 2014). The average climate data of the greenhouse, where the research was conducted, provided these conditions, and ideal conditions were created for the growing of roses in terms of temperature and humidity. The highest yield (20.6 flowers/plants) was obtained from SMC medium in which roses grown under these conditions, while HzS+P mixture took the second place. Cocopeat medium used as a control group ranked third with 17.2 flowers/plants. Different factors such as growth mediums, techniques, plant species or varieties can affect yield in different ways. Akat *et al*. (2017) reported that waste sludge application in Akito rose cultivar increased yield compared to the control, and they obtained the highest yield (13 flowers/plants) from 40% waste sludge application. Fascella and Zizzo (2005) reported that with two different growing media and four different rose varieties, growing media affected yield and quality, and perlite+coconut powder medium had the highest yield (17.7 flowers/plant) with the longest stem flowers (65 cm). Plants grow and develop by absorbing water and inorganic nutrients through their roots, so there is a linear relationship between root activity and plant growth (Kwon and Choi 2022). According to the data gathered as a result of this research, SMC, where the highest yield was obtained, may have caused an increase in the number of roots with its porous structure and its ability to drain excess water. Thus, more roots may have led to the development of a stronger crown system and higher yield. However, why did the cocopeat medium, which has almost the same characteristics of a porous structure and high water-holding capacity, have fallen to the third place in efficiency? When the analysis results of the growth medium used in the research are examined, it can be seen that the N% ratios both at the beginning and at the end of the research were higher than the cocopeat medium. In contrast, the organic C% ratios were lower in the SMC and HzS+P media, where the highest efficiency was obtained. According to Table 4, as the amount of N% increased and the amount of C% decreased, the yield increased in parallel with this situation. In other words, it can be said that there was a close relationship between the C:N ratio of the growing medium and the yield. Among other nutrients, C, N, and P are important factors for plant growth and development. These nutrients directly affect plant growth and development, microbial activities in the soil, and soil nutrient circle (Qiang *et al*. 2021). This can affect yield. It has been reported that spent mushroom compost is a very rich material in terms of organic matter, macro and micro elements (Pekşen and Yamaç 2016). Although nutrient solutions were provided to all media in ready-to-use and equal amounts, the ability of the medium to absorb these nutrients, and the gradual release of nutrients to the plant in the required proportions, depend on the structure of the growing medium. As a result, it was observed that the drainage amounts of WS and HS mediums, where the lowest efficiency was obtained, were higher than the other mediums. Therefore, it can be said that the plants grown in these media had low yields due to inadequate nutrition, as a result of the low rates of nutrient retention in these media. In addition, it was determined that the initial N values of these two media were very low and the C:N ratios were very high. During the research period, nitrogen deficiency symptoms were observed in plants grown in WS and HS media. This can be interpreted as these media being inherently nitrogen-poor during the initial stages. Due to their highly porous structure, a portion of the provided nitrogen easily drains away, while another portion converts into a gaseous form and escapes from the medium (Müftüoğlu and Demirer 1998).

Roses can be grown in soil structures including well-drained, sandy, gravelly, and loamy soils. Therefore, they can be grown in soilless agriculture in different mediums too. In the cultivation medium, it is desirable to have an EC value of 1.2 dS/m and a pH value ranging from 5.8 to 6.0 (Kwon and Choi 2022). However, it has been reported that roses can also be grown in media with a pH range of 6.5 to 7.0 (Reid 2008). In the study, it was determined that the initial and final pH values of SMC, HzS+P, and cocopeat media were at or very close to the ideal pH values reported in the literature. It was determined that the initial pH values of HS and WS mediums were very low. In addition, especially in the WS medium, the initially acidic medium experienced a very high alkalinity change (58.0%) in the final stage. In addition to other factors, such as the C:N ratio, this great change may also have a role in the WS medium's lowest values in all the parameters examined. In fact, considering this context, a great change also was experienced in the HzS+P medium. Why was the HzS+P medium the second most productive media? How have plants adapted to this change and remained unaffected? When the initial pH value (4.92) of HzS+P medium is examined, it can be seen that it was very close to the ideal pH lower limit value (5.08) for growing roses. When the final value (6.55) was examined, it was in the ideal range. Therefore, with the nutrient solutions given from the beginning, the HzS+P medium may have quickly reached the ideal pH values. When Table 1 is examined, the first flowers were cut from this medium only 38 days after planting. Hazelnut skins, which have a higher antioxidant capacity than hazelnut kernels, created the ideal medium for the nutrition of plants and may have reflected on the yield in this case (Şahin *et al*. 2019). Considering that antioxidants can be in enzyme, hormone, and protein structure, it can be said that hazelnut skins medium has a rich enzyme content, and this enzymatic activity can affect plants positively (Kurtça 2021). Why might the HzS+P environment not have ranked first in terms of the highest yield obtained? In the author's preliminary experiments, it had been determined that hazelnut skins retain an excessive amount of water and become an impermeable layer in a very short time. For this reason, hazelnut skins were mixed with perlite (3:1) and used in this way to increase the porous structure of the medium and solve this problem. However, the research results have shown that even this mixture ratio of 3:1 did not fully solve the problem. As a result, when Fig. 1 is examined, while the highest yield was obtained from this medium in the first period, the yield decreased linearly in the second and third periods in this medium. In other words, as time progressed, the drainage of the medium may have become poorly impermeable, and it may have adversely affected the yield.

Yield and quality are two separate concepts in commercial production. Generally, in cut rose cultivation, quality takes precedence during the summer months when production is high, while yield takes precedence during the winter months when production is low. The research has examined quality parameters such as flower stem length (cm), flower stem diameter (mm), flower length (cm), flower diameter (cm), flower color, and upper and lower leaf color. From these parameters, with the exception of color, the flowers cut from the cocopeat medium are generally of higher quality. This may be because the cocopeat medium is a processed material, while the other mediums are raw material. In other words, it can be said that the cocopeat medium has a more uniform structure. In this case, the flower quality can be affected. In flower colors, the darkest red flowers occurred on the hazelnut skins medium, while the lightest flowers occurred on the SMC medium. In leaf top and bottom colors, the darkest leaves occurred in SMC medium. This may be because SMC medium contains higher N content than other the medium (Table 4).

In this study investigating the use of different organic waste materials as growth medium in soilless cut rose cultivation, significant findings were obtained. According to the research findings, the SMC and HzS+P environments were identified as potential alternatives to cocopeat, which is the most commonly used organic growing medium worldwide for this purpose. The materials used in the research, with the exception of cocopeat, are raw materials that have not been subjected to any processing. Therefore, further research and efforts are needed to achieve uniformity in these materials. If these materials can be processed and made uniform, it is anticipated that there could be even greater improvements in yield and quality parameters of the products obtained from these mediums.

CONCLUSIONS

This study investigated whether different organic wastes could be used as a medium in cut flower rose cultivation, which has the largest economic share in the world cut flower sector, and several very important findings were obtained.

1. The first flowers were cut from the HzS + P (3:1) medium 38 days after the planting date. When the effect of medium on yield was examined, the highest yield value (20.6 flowers/plants) was obtained from SMC media.
2. The longest stem flowers (63.89 ± 0.947 cm) and the thickest stemmed flowers (5.86 ± 0.136 mm) were obtained from the cocopeat medium.
3. The effects of different growing mediums on flower colors were not found to be statistically significant ($p > 0.05$)

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