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Evaluation of Hazelnut Husk as a Growing Medium in Primrose Cultivation

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ABSTRACT

In this study, the effects of hazelnut husk on growth, quality parameters, and nutrient content of primrose were evaluated. For this purpose, thirteen different growing media were prepared by mixing fresh hazelnut husk (FHH) and mature husk wastes (MHH) with peat at different rates. Some physical and chemical properties of the media and nutrient analyses were made for the nutritional status of the plants. The study was carried out in greenhouse conditions with four replications according to the randomized plot design. The aeration capacity and easily available content of the growing media is within the limit values, the medias with 50% FHH and MHH were prominent in terms of air-water balance. The effect of the medium on the aesthetic appearance, total shoot, leaf, and flower number of the primrose was not significant, but it was effective on flower weight, plant height, and root fresh-dry weight. In terms of plant root-shoot development, 30% FHH and 50% MHH were prominent. The media have caused significant differences in nutrient concentrations in primrose except for nitrogen, phosphorus, and copper. The leaf phosphorus concentration was high, nitrogen and potassium concentrations were within the limit value range, iron was sufficient, and manganese and copper were insufficient, while zinc was mostly lower than limit values. When all the data are evaluated, 50% ratios of hazelnut husks can be recommended in primrose cultivation and hazelnut husk can be evaluate in ornamental plant cultivation as a growing media.

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Introduction

Urbanization's onset and increase, people's estrangement from nature and their longing for nature, the occurrence of environmental problems have increased the value of ornamental plants and led to the formation of a large market. Blok et al. (2021) stated that a 490% increase in ornamental plants is expected in the growing media market, which has the potential to increase four-fold in 40 years. Most ornamental plants are grown in greenhouses on cultivation substrates that usually contain different types of peat and perlite (Popescu and Popescu, 2015). These substrates are popular due to their easy availability, low cost, and ideal physical and chemical properties and are successfully used as growing media for ornamental plant production (Abad et al., 2001; Agarwal et al., 2021). However, peat is a non-renewable material and will become more expensive in the near future due to the decline in peatland reserves (Maher et al., 2008). Therefore, it is necessary to find renewable, high-quality, and low-cost substrates as alternatives to peat (Pascual et al., 2018; Feng et al., 2020). Orsini et al. (2013) stated that various new, sustainable growing media have been identified from agricultural, industrial, and urban waste products, and this will create opportunities for alternative waste management and production. Jurgilevich et al. (2016) noted that reusing these waste products as soilless growing media will create both new products and markets and encourage their use as direct raw materials for food production. In particular, the sustainable use of traditional soil-based farm waste will directly initiate a regenerative process within the agriculture system. Gruda and Braqq (2021) stated that it is possible to use alternative organic materials (such as production residues, harvest waste, and composted materials) based on locally produced different material components and mixtures as growing media components to reduce peat use.

Substrates have their own unique characteristics and are usually different from each other. The quality of the growing medium is one of the main factors affecting the success of the cultivation (Raviv and Lieth, 2007) and is directly related to the quality of the materials used in the growing medium formulations (Reis and Coelho, 2007). Growing media should provide a suitable biological and chemical environment in addition to a suitable physical structure for plant roots to effectively access nutrients. Additionally, it should meet the practical and economic requirements of the grower (Barret et al., 2016).

Hazelnut is cultivated for their fruits in many regions of the world. Turkey is one of the leading hazelnut producers in the world, with an annual production capacity of 684.000 thousand tons on 738.900 hectares of production area, and it is one of the most important agricultural products of the country (Black Sea Exporters' Association, 2022). Hazelnut husk is a plant-based waste that is generated after the harvest of hazelnuts. Approximately 1/5 of dry husk remains from 1 kg of fresh harvested hazelnuts, which creates a significant organic waste potential. However, these wastes are still not evaluated and are mostly causing important environmental problems by being burned on the roadside. The husk has a high C/N ratio (33/1) due to its low nitrogen and high carbon content, making it a difficult-to-decompose material. Therefore, it needs to be composted (Çalışkan et al., 1996) or left under natural conditions before being mixed into the soil (Özenç and Özenç, 2008). Özenç (2005) indicated that the 2-4 mm particle size of husk compost was more acceptable in terms of physical properties, while the 0-2 mm particle size was more effective in term of chemical properties. Also, pH and EC values of all particle sizes are within acceptable limits as a growing medium. Özenç and Özenç (2008) stated that the effects of hazelnut husk applications as an organic regulator on the physical fertility of the soil could be clearly observed two years later. In laboratory and pot studies, it has been demonstrated that hazelnut husk regulates the physico-chemical and biological properties of soils (Zeytin and Baran, 2003; Özenç et al., 2019; Tarakçıoğlu et al., 2019; Irmak Yılmaz and Eltutmaz, 2019; Irmak Yılmaz, 2020) and positively affects plant growth (Özenç, 2008; Yılmaz and Özenç, 2012; Sezer and Özenç, 2018).

On the other hand, studies have been carried out on the possibilities of using hazelnut husk as a media component in ornamental plant cultivation. In studies with *glass beauty* (Dede et al., 2006), *cupressus macrocarpa* and *thuja occidentail* (Özdemir et al., 2017), *primula obconica* (Najafi et al., 2019), *salvia splendens* (Çiçek ve Yücedağ, 2021) and *wild pancy* (Çiçek et al., 2021), it has been reported that hazelnut husk positively affected plant growth and can be recommended as a media component. Dede et al. (2011) reported that hazelnut husk has great potential to be used as a growing medium in potted plant production due to its high stability, but the particle size should be considered when used as a growing medium. The researchers also noted that, depending on the degradation, the properties of hazelnut husk change, and therefore, the 0-2 mm particle size could be an alternative growing media component for potted plants in terms of both aeration and water holding capacity.

Primrose vulgaris, a decorative plant with eye-catching flower colors, is grown in organic material-based media and pots, like many ornamental plants. This study is aimed to investigate the effects of the media prepared with hazelnut husk with different ratios and maturation times on the growth, some quality characteristics, and various nutrient content of primrose (*Primula vulgaris*), which has a high sales value. Thus, it is believed that supporting the usability of hazelnut husk waste in ornamental plant cultivation can lead to significant economic gains through natural resource recovery and conservation.

Materials and Methods

Growing Media

Hazelnut husks, which were kept for different periods under natural conditions, were used as media components in the study. Hazelnut husks were obtained from producer gardens. The husk from a pile waiting about two years was called fresh hazelnut husk (FHH), and the husk from a pile waiting more than five years was called mature hazelnut husk (MHH). Commercial peat (Suli Flor- Propagation Substrate/SF1-Lithuania) was purchased. The media components were dried in a cool, shady place in the laboratory until excess moisture was removed, and they were sieved through a 4 mm sieve to ensure homogeneity. Then, FHH and MHH were mixed with peat to prepare media. The following mixtures were used (v/v): C: 100% peat, FHH: 100% FHH, MHH: 100% MHH, FHH1: 90% peat+10%FHH, FHH2: 80% peat+20%FHH, FHH3: 70% peat+30%FHH, FHH4: 60% peat+40%FHH, FHH5: 50% peat+50%FHH, MHH1: 90% peat+10%MHH, MHH2: 80% peat+20%MHH, MHH3: 70% peat+30%MHH, MHH4: 60% peat+40%MHH, MHH5: 50% peat+50%MHH. A total of 13 husk-based growing media were prepared. Some physico-chemical properties of the media components before the experiment are given in Table 1.

Table 1. Basic physico-chemical properties of media components and some nutrient content

Properties	Peat	FHH	MHH
Bulk density (g cm^{-3})	0.123	0.107	0.085
Total porosity (%)	77.10	69.50	84.82
Aeration capacity (%)	18.84	26.85	27.64
Easily available water content (%)	26.92	17.60	21.64
pH	5.13	5.93	7.68
EC (dS m^{-1})	0.231	0.561	0.230
Organic matter (%)	96.72	81.67	71.45
Total nitrogen (%)	0.89	0.96	1.39
Total phosphorus (%)	0.03	0.05	0.12
Total potassium (%)	0.04	0.16	2.04
Total iron (mg kg^{-1})	303.6	680.2	433
Total manganase (mg kg^{-1})	14.15	112.85	178.35
Total copper (mg kg^{-1})	3.6	4.3	8.05
Total zinc (mg kg^{-1})	18.35	11.05	17.30

The suitability of the growing medium was tested on primrose (*Primula Vulgaris*). The primrose was purchased in the form of rooted, 3-5 leaf seedlings from a horticultural production and sales company (Çotanak Peyzaj Sanayi Tic. Ltd. Şti., Ordu).

Experimental Setup

The experiment was carried out between October and December 2018 at the Soil and Plant Nutrition Research Greenhouse of Giresun Hazelnut Research Institute. The experiment was set up in a randomized plot design with four replications, and a total of 52 pots were used. Growing media were prepared and filled into 1000 cm^3 plastic pots on October 24, 2018, which were then moistened at intervals, and the media were prepared for transplanting. On October 29, 2018, one primrose seedling was planted in each pot, and only distilled water was used for irrigation during the first three weeks until plant roots compatibility was achieved. Thereafter, the plants were irrigated from the surface once or twice a week with nutrient solution (Hoagland and Aron 1950) until harvest (60 days) on November 17, 2018. At the end of the experiment, the changes in some phenological characteristics were recorded: the number of shoots and leaves (counted in each plant from the beginning of flowering), average flower weight, and plant height (measured from the media surface to the tip of the plant), and an aesthetic appearance score were given for the overall performance of the plants. Subsequently, the plants were cut above the media surface. For the root part of the plant, the pots were poured onto a sieve, and the roots were carefully washed to completely separate from the medium. Root and leaf parts were washed once with tap water and twice with distilled water; excess water was removed with blotting paper; and their fresh weights were measured on a precision balance. Root and leaf samples were dried in a forced-air drying cabinet at 65-70°C for 48 hours, and their dry weights were measured.

Media and Plant Analyses

Physical properties of media: The moisture contents of medias were measured by using intact metal cores of 37 mm length and 44 mm diameter. Experiment of hanging water column was conducted for determination the water content at lower suction near saturation in the range of 0, 1 and 5 kPa. Total porosity (TP), bulk density (BD), the aeration porosity (AC), and easily available water content (EAW) were calculated using soil moisture data as mentioned by De Bood et al. (1974). The bulk density and the aeration capacity were calculated from the amount of air in the 1 kPa suction, and the easily available water content was calculated from the difference between the moisture contents in the 1 and 5 kPa suctions. The organic matter content was determined by calculating the organic matter losses (%) by dry combustion at 550±25°C for 4 hours (DIN 11542, 1978). pH and EC were measured in a 1:3 (w/v) water-soluble extraction (Gabriels and Verdonck, 1992).

Mineral element contents of leaf samples and growing media were determined according to Kacar and İnal (2008). Dry samples were ground and sieved at 0.5 mm. Total nitrogen (N) content was determined by the Kjeldahl method by Bremner (1965). Total potassium (K), iron (Fe), copper (Cu), manganese (Mn) and zinc (Zn) analyzes were determined by atomic absorption spectrophotometer in the samples burned by dry burning method and extracted with hydrochloric acid (33%). Total phosphorus (P) concentration was determined by a spectrophotometric method (Kacar and İnal, 2008).

Experimental data were subjected to an analysis of variance (ANOVA) with the use of Minitab 17.0 statistical software. Significant means were compared with the use of the Tukey's test at the 5% significance level and the results were expressed in the form of a letter notation along with the averages.

Results and Discussion

Some Physical Properties of Media

Some physical properties of the growing media prepared by mixing different ratios of FHH and MHH are given in Table 2. The bulk density of the media ranged between 0.085-0.123 g cm^{-3}. The lowest value was found in 100% MHH, and the highest was found in 100% peat media. Depending on the bulk density of the main components, the bulk density of the media decreased as the ratio of fresh and mature hazelnut husk added to the peat increased.

Table 2. Some physico-chemical properties of growing media

Media	TP (%)	BD (g cm^{-3})	EAW (%, v/v)	AC (%, v/v)	OM (%)	pH	EC (dS m^{-1})
Control (100:0)	77.10	0.123	26.92	18.84	96.72	5.13	0.231
FHH (100:0)	69.50	0.107	17.60	26.85	81.67	5.93	0.561
MHH (100:0)	84.82	0.085	21.64	27.64	71.45	7.68	0.230
FHH1 (90:10)	71.69	0.121	20.67	25.91	93.98	5.15	0.330
FHH2 (80:20)	75.41	0.119	20.74	29.02	92.35	5.10	0.351
FHH3 (70:30)	72.82	0.118	22.35	26.52	91.96	5.09	0.560
FHH4 (60:40)	74.13	0.116	20.06	25.30	91.74	5.19	0.417
FHH5 (50:50)	73.97	0.119	25.03	25.82	90.02	5.24	0.445
MHH1 (90:10)	74.04	0.119	23.89	19.76	92.55	5.28	0.373
MHH2 (80:20)	70.96	0.115	21.43	22.42	88.72	5.49	0.426
MHH3 (70:30)	80.56	0.111	21.96	27.49	86.75	5.69	0.505
MHH4 (60:40)	81.54	0.107	22.05	30.31	83.42	6.03	0.537
MHH5 (50:50)	79.30	0.105	22.33	26.76	80.98	6.28	0.662
ID*	>85	<0.4	20-25	20-30	>80	5.2-6.3	0.75-1.19

*According to De Boodt and Verdonck (1972), Abad et al. (2001) and Nougera et al. (2003); AC: Aeration capacity, EAW: Easily available water content, BD: Bulk density, OM: Organic matter content, EC: Electrical conductivity

Although the bulk density of all main components is within the limit values (<0.4 g cm^{-3}) (Abad et al., 2001), it is considerably lower than the values accepted as the optimum range (0.2-0.4 g cm^{-3}) (Nougera et al., 2003). Agarwal et al. (2021) reported that a high bulk density increases transportation costs, while a very low bulk density adversely affects mixability in plastic containers. For other properties, an ideal potting medium has a total porosity of 70-90% (Abad et al., 2001; Nougera et al., 2003), aeration capacity of 20-30%, and an easily available water content of 20-25% (De Bood and Verdonck, 1972). The aeration capacity of the growing media ranged from 18.84% to 30.31%, while the available water content varied from 17.60% to 26.92%. As can be seen in Table 2, the aeration capacity of the peat medium is lower than the other media components. The addition of FHH and MHH to peat ensured that the aeration capacity of the media remained within the recommended limits. The husk materials with high aeration capacity had a positive effect on all growing media, and the highest values were found with 40% MHH (30.31%) and 20% FHH (29.02%) additions.

On the other hand, the easily available water content of the main components, except fresh hazelnut husk, is above the limit values in the peat medium and within the limit values in the mature hazelnut husk medium. The easily available water content of all media was within the limit values, the high-water holding property of peat has been the main factor in balancing the easily available water content of the medias for FHH media. Based on these findings, for the air-water balance, media with 50% of FHH and MHH media stand out. Özenç (2008) reported that medium with peat supplemented with 50% and 75% hazelnut husk compost provided ideal conditions in terms of easily available water content and aeration capacity. Dede et al. (2011) reported that the water holding capacity of hazelnut husk changes depending on the degree of decomposition and that it has a low water holding capacity compared to the high porosity and aeration capacity of the raw material. They explained that the highly aeration capacity of raw hazelnut husk could be brought closer to the ideal values by adding perlite (Dede and Özer, 2018). Najafi et al. (2019) determined that the easily available water content and buffering capacity of five different media formed from a mixture of peat and hazelnut husk were at recommended levels, whereas the aeration capacity values were lower than the limit values, excluding 100% hazelnut husk.

As seen in Table 2, the organic matter contents of the growing media varied between 71.45% and 96.72%. Peat had the highest organic matter content; it is above the ideal limit value in the FHH media but lower in the MHH media. The reason for organic matter loss can be explained by the fact that MHH material has decomposed for more than 5 years (Özenç and Özenç, 2009). Dede et al. (2011) showed a gradual decrease in organic carbon fractions according to the degree of decomposition in decomposed husk samples. It was stated that the amounts of lignin and cellulose were high due to the presence of woody material and empty hazelnut shells in husk wastes, while the amount of hemicellulose was insignificant low. Nevertheless, due to the high organic matter content of peat, the organic matter contents of all FHH and MHH added media were within the ideal limits. Beretta and Ripamonti (2021), in their study comparing the effect of wood fiber at different rates instead of peat to reduce the environmental impact in ornamental plant production concluded that wood fiber at a rate of 30% and 50% is a valid alternative to peat in potted plant cultivation.

The pH values of the growing media ranged from 5.10 to 7.68, and the EC values ranged from 0.230 to 0.662 dS m^{-1}. The media pHs were varied between slightly acidic and slightly alkaline, and no salinity problem. The pH values of peat and FHH media were close to each other, while the pH of 100% MHH media was higher. Probably, during the decomposition process, the medium became neutral due to natural leaching, and the changes were less. Therefore, as the ratio of mature husk mixed with peat increased, the pH value of the media also increased, and the pH of the media was measured as at 6.28 with 50% MHH addition. Najafi et al. (2019) showed that the pH values of the media prepared with hazelnut husk were higher in 100% husk media, and the low pH content of peat increased with husk addition. When the EC values of peat and MHH materials were close, and FHH material was higher, but there was no salinity problem. The highest EC value was measured with 50% MHH addition, and the lowest with 10% FHH addition. The pH and EC values of all media were within the limit values specified by Abad et al. (2001). Özenç (2008) explained that adding 50% and more husk compost to peat provided significant improvements in the chemical properties of the media. Dede et al. (2011) stated that the pH, EC, and nutrients of medium and strongly decomposed husk material, except for raw husk, were within acceptable limits. Özdemir et al. (2017) reported that the physicochemical properties of four different growing media, prepared from regional wastes such as hazelnut husk, rice husk, corn straw, and straw dust, were within the ideal limits.

Plant Growth

The effect on some growth parameters of primrose grown in the media prepared by mixing MHH and FHH at different proportions with peat resulted in statistically significant differences (Table 3), but the effect on the aesthetic appearance score, the total number of shoots, leaves and flowers did not have a statistically significant.

The average aesthetic appearance score of the plants varied between 8.12 and 9.62, the total number of shoots 8.25-16, the number of leaves 10.5-15.25, the number of flowers 8.5-15.75 (not shown in the table). In terms of these characteristics, media supplemented with 10% and 20% FHH, and 10% and 50% MHH stood out. The effect of husk materials on the visual development of plants was found to be remarkable. Also, total flower weights varied between 4.13 and 9.71 g. The lowest weight was observed in the plants grown in peat, while the highest was found with 10% MHH addition, resulting in a 2.35-fold increase in flower weight compared to peat media. This was followed by a 2.24-fold increase in flower weight with 50% MHH addition (Table 3). High flower weight is an indication that the plants in the media produce larger, showy, and quality flowers. Flower formation is a result of good vegetative development, and vegetative development is closely related to the physical and chemical properties of the medium.

Table 3. Some growth characteristics of primrose

Growing Media	TFW (g)	SFW (g)	SDW (g)	RFW (g)	RDW (g)	PH (cm)
Control (100:0)	4.13^{d}	14.42	1.99	5.14^{b-e}	0.66^{bc}	16.37^{a}
FHH (100:0)	5.10^{c-d}	17.41	2.11	5.05^{b-e}	0.64^{bc}	12.25^{ab}
MHH (100:0)	5.38^{b-d}	12.81	1.71	3.30^{e}	0.50^{c}	10.62^{b}
FHH1 (90:10)	5.11^{cd}	14.33	1.93	6.94^{a-c}	0.82^{a-c}	13.12^{ab}
FHH2 (80:20)	6.07^{a-d}	16.79	2.25	5.95^{a-e}	0.79^{a-c}	13.50^{ab}
FHH3 (70:30)	6.17^{a-d}	15.36	2.12	8.18^{a}	1.01^{ab}	12.75^{ab}
FHH4 (60:40)	7.47^{a-c}	16.36	2.06	5.59^{a-e}	0.68^{b-c}	11.75^{b}
FHH5 (50:50)	7.89^{a-c}	18.47	2.53	6.22^{a-d}	0.80^{a-c}	13.37^{ab}
MHH1 (90:10)	7.47^{a-c}	13.59	1.74	5.01^{c-e}	0.68^{bc}	11.12^{b}
MHH2 (80:20)	7.45^{a-c}	14.98	2.17	7.84^{ab}	1.17^{a}	11.62^{b}
MHH3 (70:30)	8.49^{ab}	16.39	2.25	6.66^{a-d}	1.02^{ab}	13.62^{ab}
MHH4 (60:40)	7.86^{a-c}	16.90	1.87	4.03^{de}	0.66^{bc}	11.25^{ab}
MHH5 (50:50)	9.27^{a}	17.93	2.36	5.49^{a-e}	0.70^{bc}	12.00^{b}
Anova	***	ns	ns	***	***	**

***,**, ns: P<0.001, 0.01, non-significant. The difference between the mean of at least two groups was found to be statistically significant. The difference between the means denoted by the same letter is not significant within its group; TFW: Total flower weight, SFW: Shoot fresh weight, SDW: Shoot dry weight, RFW: Root fresh weight, RDW: Root dry weight, PH: Plant height

Table 4. Some nutrient elements concentrations of primrose

Growing Media	N (%)	P (%)	K (%)	Fe (mg kg^{-1})	Mn (mg kg^{-1})	Cu (mg kg^{-1})	Zn (mg kg^{-1})
Control (100:0)	3.89	0.57	1.31^{d}	105.32^{ab}	29.40^{ab}	10.15	7.97^{c}
FHH (100:0)	3.86	0.62	1.82^{ab}	85.62^{a-d}	18.65^{ab}	12.15	9.82^{bc}
MHH (100:0)	3.60	0.43	2.01^{ab}	70.82^{c-d}	16.50^{b}	12.37	9.83^{bc}
FHH1 (90:10)	3.81	0.62	1.48^{b}	81.72^{a-d}	33.45^{a}	9.43	9.95^{bc}
FHH2 (80:20)	3.82	0.53	1.47^{b}	60.10^{d}	31.07^{ab}	7.90	10.17^{bc}
FHH3 (70:30)	3.72	0.57	1.69^{ab}	72.65^{b-d}	30.97^{ab}	9.18	13.00^{bc}
FHH4 (60:40)	3.90	0.55	1.77^{ab}	68.36^{cd}	24.83^{ab}	11.73	27.00^{a}
FHH5 (50:50)	3.72	0.56	1.53^{b}	62.25^{cd}	26.22^{ab}	11.60	25.67^{a}
MHH1 (90:10)	3.47	0.41	1.93^{ab}	58.36^{d}	28.85^{ab}	10.05	17.95^{a-c}
MHH2 (80:20)	3.40	0.54	2.65^{a}	65.62^{cd}	26.80^{ab}	10.08	21.06^{ab}
MHH3 (70:30)	3.50	0.45	2.07^{ab}	84.08^{a-d}	26.55^{ab}	8.80	17.22^{a-c}
MHH4 (60:40)	3.85	0.44	1.76^{ab}	96.05^{a-c}	33.97^{a}	10.65	17.52^{a-c}
MHH5 (50:50)	3.80	0.57	1.68^{ab}	111.37^{a}	26.32^{ab}	8.60	16.30^{a-c}
Anova	ns	ns	*	***	*	ns	***

***, *, ns: P<0.001, 0,05, non-significant. The difference between the mean of at least two groups was found to be statistically significant. The difference between the means denoted by the same letter is not significant within its group.

It is thought that media prepared with MHH material stand out due to its high nitrogen, phosphorus and potassium content, and slightly alkaline reaction, and increased availability of nutrients resulting from decomposition. Erdoğan (2004) explained significant differences in the average flower weight of primula plants as a positive effect of higher uptake of K, P, and Fe on flower formation and quality. Popescu and Popescu (2015) reported that the physiological potential of petunias and ornamental tobacco is significantly influenced by the potting media in which they are grown and that the responses of the growing media to flowering varied greatly between plants. Bağcı et al. (2011), Najafi et al. (2019), Çiçek et al. (2021) stated in their studies that coconut coir waste, peat-based hazelnut shell and husk media positively influenced quality parameters such as shoot number, total flower number, number of leaves of Primula obconica and salvia plants, and they have determined that the media with 50% hazelnut husk is the most effective media.

Growing media caused significant differences on root fresh and dry weights of the primrose plant; average root fresh weights were 3.30-8.18 g, dry weights varied between 0.50-1.17 g (Table 4). The highest fresh and dry weights were found in media where 30% FHH and 20% MHH were added, resulting in a 59% and 77% increase compared to the control, respectively. The air-water balance of the media prepared with 30% FHH and MHH additions is within acceptable limits (Table 2), which supports our findings. In plant root development, the air-water balance of the media is the most important physical factor in terms of providing the oxygen required for root respiration and facilitating the roots' access to water. In this way, it also supports root development and growth by ensuring that photosynthesis products are transported to the roots when necessary, during the root growth process. Çiçek and Yücedağ (2021) stated that the maturity time of hazelnut husk positively affected the growth and quality characteristics of wild pancy with an increased application rate. Similarly, Tarakçıoğlu and Özenç (2022) determined that lettuce grown in hazelnut husk, hazelnut husk:peat (1:1) medias were more effective on leaf and root fresh-dry weights, and that vermicompost applications to these media supported the development. In addition, the effect of plant nutrients on root growth, morphology, and distribution should also be considered. Especially nitrogen is the most effective nutrient element in root development, followed by phosphorus (Kacar and Katkat, 2010). Therefore, the higher nitrogen and phosphorus content of growing media materials compared to peat should not be overlooked as other influential factors (Table 1).

Growing medias did not cause significant differences in the shoot fresh and dry weights of primrose plants; the average shoot fresh weights ranged from 12.81g to18.47 g, and dry weights ranged from 1.71g to 2.53 g (Table 4). The additions of 50% FHH and 20% and 50% MHH had a greater effect on shoot growth. The addition of 50% FHH was obtained with the highest fresh-dry weights, with an increase of 28% in fresh weight and 19% in dry weight. The additions of 20% and 50% MHH also contributed increase of 23% and 12% in fresh-dry weights, respectively. The physicochemical properties of these media, as well as the sufficient and excessive levels of nutrient content in the materials used as the main components, indicate that the plant utilizes the photosynthetic products during shoot development. This is consistent with our findings regarding the effects of water uptake and transport by roots on the visual development (such as the number of leaves-shoots-flowers, and total flower weight) of plants. Plant growth differs according to many environmental factors, in addition to the characteristics of the growing medium used by the plant species. The findings about the potential use of hazelnut waste in the cultivation of various ornamental plants served as a reference for our study. Dede et al. (2012) stated that the mixture of hazelnut shell and biosolid can be used in the cultivation of ornamental palm, and that the main factor affecting plant growth is the high nitrogen content of the substrate, as well as the positive relationship between leaf nitrogen content and plant dry weight. Najafi et al. (2019) stated that the effect of hazelnut husk waste on the fresh and dry weight of the primula plant is significant, with the highest fresh weight found in medium containing 100% hazelnut husk waste, and the highest dry weight found in 50% peat + 50% hazelnut husk waste. Özdemir et al. (2017) investigated the effects of four different growing media prepared from locally available agricultural residues, namely hazelnut husk, rice hull, corn straw, and sawdust were composted by mixing with municipal wastewater biosolid (1:1 v/v), on the growth parameters of ornamental plants. According to Pearson correlations and stepwise regression analysis results, nutritional properties such as carbon-nitrogen ratio, cation exchange capacity, humification index, and total phosphorus and potassium were found to be the most effective. Similar studies with different growth media have also reported significant relationships between plant growth and nutrient content. Garcia-Gomez et al. (2002) reported that the physicochemical properties of the media and the nutrients (N and K) supplied from the compost particularly affected the growth of the calendula plant grown in 16 different growing media prepared from various wastes, peat, and commercial substrates. Omidi et al. (2019) showed in their study on the use of peanut shell compost and its combinations as an alternative source in ornamental plant cultivation that peanut shell compost had a significant effect on the number of flowers, plant height, and fresh and dry root-stem weight of mixed color violet compared to the control.

The plant height of the primrose varied between 10.62 and 16.37 cm, with the highest plant height measured in 100% peat medium and the lowest in 100% MHH medium. Among the media prepared, the addition of 20% FHH and 30% MHH to the peat became prominent. Burgel et al. (2020) determined that different growth substrate components, including peat, green fiber, and coconut coir, affected the plant height and leaf dry weights of cannabis, with higher leaf N content observed in the green fiber-based medium compared to the peat-based medium. They also mentioned that organic green fibers, which can partially replace decomposed peat for homogeneous plant growth, can be selectively chosen according to the genotype.

Nutrient Content

Some nutrient content of primrose grown in growing media prepared by mixing peat with FHH and MHH at different ratios are given in Table 4.

Although the statistical significance of the effect of the growing media on the N content of primrose was not found, N contents varied between 3.4% and 3.9% (Table 4). The optimal level of N content for ornamental plants grown in pots was reported to be in the range of 1.5% to 4.5% by Poole et al. (1981). Kütük et al. (1998) explained the nutrient differences of ornamental plants grown by applying the same nutrient solution in different media based on the physical and chemical properties of the media. Erdogan (2004) determined that the N content of primula plant varied between 2.54% and 3.43% depending on the medium. Najafi et al. (2019) found that the N content of Primula obconica flowers grown hazelnut husk- containing media varied between 3.40% and 4.01% and decreased with increasing husk content.

On the other hand, Çiçek et al. (2021) found that the N content of Salvia splendens grown in media where the husk waste was used ranged from 3.1% to 4.2% and was higher in media with 30% or more husk content. Similarly, Çiçek and Yücedağ (2021) found significant differences in the nitrogen content of wild pancy ranging from 2.2% to 4.5% and identified the media with 20% three-year-old husk waste as the most effective. Our findings seem to be consistent with these studies.

The total P content of the primrose varied between 0.41% and 0.62% and the effect of the medium was not statistically significant (Table 4). The phosphorus content of the plants was higher than the critical values of 0.15% to 0.30%, which were described as optimum levels for ornamental plants grown in pots by Poole et al. (1981). Jones et al. (1991) reported phosphorus levels of 0.30% to 0.75% for begonia plants. As seen in Table 4, fresh husk material was more effective than peat and mature husk in terms of the phosphorus content of the plants. Although the phosphorus content of mature husk material was higher than that of the other materials (Table 1), its availability to the plant was low. It has been stated that phosphohumic components, which are decomposition products of organic matter, can be easily taken up by plants, but the mechanism of this process is not fully elucidated (Kacar and Katkat, 2010). Anions released as decomposition products of organic materials form immobilized compounds with Fe and Al, which is thought to be the reason for the reduced availability of phosphorus.

The total K content of primrose varied between 1.31% and 2.65%; Poole et al. (1981), when compared with the optimum potassium level (1.50-5.00%) in ornamental plants grown in pots, it was seen to be at a sufficient level. As seen in Table 4, mature husk material was more effective than peat and fresh husk in terms of the potassium content of the plants. This effect is directly related to its high potassium content (2.04%) of the mature husk material (Table 1). The highest potassium content was found in plants grown in a medium with 20% MHH addition to the peat, and the lowest in the plants grown in 100% Peat (control) medium. It has been shown in many studies that hazelnut husk is a special material in terms of its high potassium content (Çalışkan et al. 1996; Özenç, 2005; Kacar and Katkat, 2010). It is known that potassium affects the quality characteristics of plants because plants take most of the potassium during the vegetative growing period (Kacar and Katkat, 2010). When the results of the investigated vegetative parameters of primrose are compared with these findings, it can be seen that the results are consistent. Çiçek et al. (2021) and Çiçek and Yücedağ (2021) reported that media with 50% hazelnut husk waste had the highest P and K contents for Salvia splendens, and media with 20% three-year-old husk were more effective for wild pancy. There are many factors that affect the uptake of potassium by plants. In addition to plant variety, the available water content and aeration capacity of the media are important physical factors. As the amount of water taken up by plant roots increases, potassium uptake also increases, and in cases where aeration is insufficient, potassium uptake in plants decreases significantly (Kacar and Katkat, 2010). It was observed that media with these characteristics had a positive effect on the K content of primrose. Najafi et al. (2019) stated that the increase in the rate of hazelnut husk in the media had an enhancing effect on the potassium absorption of the primula plant.

The total Fe content of the primrose ranged from 58.36 to 111.37 mg kg^{-1}, Mn content ranged from 16.5 to 33.97 mg kg^{-1}, Cu content ranged from 7.9 to 12.37 mg kg^{-1}, Zn content ranged from 7.9 to 27.0 mg kg^{-1} (Table 4). Jones et al. (1991) expressed the sufficient threshold values for Fe and Mn as 50-200 ppm, Cu as 7-30 ppm, and Zn as 25-200 ppm for begonia plants. When compared with the data of the researchers, the plant is sufficient in terms of Fe, insufficient in terms of Mn and Cu, and mostly below the threshold values for Zn. Peat material was more effective on the Fe and Mn content of the plant, while husk materials were more effective on the Cu and Zn contents. The highest Fe content was found in plants grown in a medium with 50% MHH addition. Plants take up Fe through active root tips, so Fe uptake is weakened under conditions of insufficient moisture depending on damage to the plant roots. Considering this evaluation, it can be assumed that the medium with 50% MHH addition promotes Fe uptake due to its sufficient aeration and water capacity (Table 2). The highest manganese content in plants was found in media with 40% MHH and 10% TFZ added to peat, while the lowest content was found in plants grown in 100% MHH medium. Although the hazelnut husk materials have a high Mn content compared to peat, their availability to plants is limited due to their high pH, and they cannot be used by plants due to strong adsorption in organic fractions. Çiçek et al. (2021) reported that a medium with 20% two-year-old husk was more effective on the Fe and Mn content of Salvia splendens, while Çiçek and Yücedağ (2021) determined that wild pancy grown in media with hazelnut husk had sufficient levels of other nutrient elements except manganese. Hazelnut husk materials, especially mature husk material, were more effective than peat on the total copper content of broadcloth. The Cu content of mature husk material is higher than that of the other two materials (Table 1), and the highest copper content was found in plants grown in 100% MHH medium. The copper content in plants is relatively lower compared to other microelements as copper binds more strongly to organic matter and its availability changes accordingly. The fact that the mature hazelnut husk material has undergone advanced decomposition and turned into a structure called humus indicates that Cu increases its availability. The highest zinc content was found in plants grown in media where 20% MHH and 40% FHH were added to peat, and the lowest in plants grown in 100% peat (control) medium. The availability of zinc is directly related to organic matter and increases or decreases depending on the complexes formed with fulvic and humic acid components. Therefore, both fresh and mature husk materials are thought to be effective, depending on the organic complexes they possess. In their study, Çiçek et al. (2021) investigated the effect of the nut husk's maturation time and nutrient solution on the development and nutrient content of pansies. Upon evaluating all the results, they reported that the application of 20% one-year husk + nutrient solution in peat/perlite medium was the most effective medium. Additionally, a common finding in several studies is the antagonistic effect between Zn and Fe, as well as between Zn and P, resulting in reduced uptake (Kacar and Katkat, 2010). In our study, it was observed that the Zn content decreased in primroses with high Fe and P contents.

Conclusion

In this study, the characteristics of growing media composed of peat mixed with fresh and mature hazelnut husk materials for ornamental plant cultivation in pots, as well as the growth characteristics and nutrient element contents of primrose (*Primula vulgaris*), were investigated. The growing media were close to or within the optimum limits in terms of their physicochemical properties for plant growth, thus positively affected root and shoot growth, as well as number and weight of flowers. 50% FHH and MM media were more suitable in terms of air-water balance, the effects of 30% FHH and 20% MHH on plant growth were also remarkable. Additionally, the nutrient element concentrations of primrose varied depending on the growing medium, but deficiencies of Zn, Mn, and Cu contents were found. Nevertheless, no deficiency symptoms were observed in the plants, and all plants reached sales quality. When all the examined properties were evaluated together, growing media with 50% FHH and MHH mixed with peat can be recommended, and micro-element fertilization should be emphasized. As a result, hazelnut husk, which is a byproduct of hazelnut grown for its fruit in many regions of the world, can be considered as a growing media component in ornamental plant cultivation due to its low cost and appropriate physicochemical properties. This can contribute to the conservation of the environment and natural resources by utilizing the large quantities of hazelnut husk waste generated.

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Conflict of interest

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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