# Reuse of Sewage Sludge with Regards to Sustainability in Taurus Snowdrop Culture

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This study was aimed to determine the possibility of reusing sewage sludge in the cultivation of Taurus snowdrop (*Galanthus elwesii* Hook. f.). Taurus snowdrop bulbs with a circumference of 4 cm were used as plant material in the experiment. Bulbs were planted in five different growing media, 100% soil, 25% sewage sludge+75% soil, 50% sewage sludge+50% soil, 75% sewage sludge+25% soil, and 100% sewage sludge. The bulb diameter ranged between 16.8 and 18.5 mm, and bulb weight varied between 2.74 g and 6.33 g. The greatest bulblet weight (2.17 g) and leaf thickness (0.90 mm) obtained was in 75% sewage sludge+25% soil mixture. The number of bulblets ranged from 1.0 to 1.33 piece/bulb. Leaf length was between 7.30 and 9.25 cm, and leaf width was 9.7 to 11.6 mm. The effects of growing media on pedicle length, pedicle diameter, and fruit diameter were not found to be significant. Pedicle lengths were between 4.39 and 6.38 cm, pedicle diameters ranged from 1.59 to 1.80 mm, and fruit diameters were between 4.40 and 7.40 mm. It was concluded based on the present findings that 75% sewage sludge+25% soil mixture could reliably be used as a growing media for Taurus snowdrop culture.

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## INTRODUCTION

Increase in population of cities with the migrations from rural section to urban areas, as well as industrial and technological developments are all rapidly increasing the quantity of waste generated in cities (Karacocuk *et al*. 2022; Isinkaralar *et al*. 2024). Domestic and industrial wastewater should pass through wastewater treatment facilities before it discharges to receiving water bodies. According to 2020 municipal wastewater statistics of Türkiye, annually 5 billion $m^3$ wastewater was collected through sewage networks and 3.9 billion $m^3$ of this amount was treated in wastewater treatment facilities. Of this treated water, 49.2% were discharged into rivers, 38.5% into sea, 3.1% into dams, 1.3% into lakes-earth-fill dams, 0.4% into land, and 7.5% were discharged into other receiving bodies. The amount of wastewater per capita was calculated as 189 L (TUIK 2020). As a result of wastewater treatment processes, sewage sludge is formed together with treated water. Sewage sludge is generated with the treatment of wastewater. Sewage sludge has a solid content of 0.25 to 12%. It is usually disposed through thickening, stabilization, digestion, dewatering, composting, conditioning, disinfection, drying, land use, regular storage, incineration methods, *etc*. (Yildiz *et al.* 2009; Ozturk *et al.* 2015).

The most important problem with sewage sludge is heavy-metal pollution. Heavy-metal contamination in sewage sludge is known to reach high levels. Heavy metals are among the most harmful pollutants to living organisms. Some can be toxic, carcinogenic and fatal even at low concentrations. Even those that are essential nutrients for living organisms can be harmful at high concentrations. They can also remain intact in nature for a long time and bioaccumulate in living organisms (Savas *et al*. 2021; Isinkaralar *et al.* 2022; Istanbullu *et al.* 2023; Ghoma *et al.* 2023). The application of sewage sludge improves soil conditions and nitrogen (N), phosphate (P) and potassium (K) concentrations in it. However, it can cause environmental risks such as pollution of soil profiles, water resources, and even the food chain due to the accumulation of heavy metals (Pan *et al.* 2021). Therefore, monitoring and reducing the change of heavy metal pollution is a priority research topic. For this purpose, plants can be very useful in phytoremediation studies (Isinkaralar *et al*. 2023; Sulhan *et al.* 2023; Koç *et al.* 2024).

Reuse of sewage sludge in agricultural fields is an economical and environment-friendly approach for the disposal of huge quantities. It is possible to reduce fertilizer costs with the organic matter and nutrients of sewage sludge (Demirkan *et al*. 2014; Akat *et al.* 2015; Tampere *et al.* 2015). Sewage sludge is reused in agricultural and forest lands, mine quarries, degraded sites, parks-gardens, landscapes, and nurseries (Kucukhemek *et al.* 2005; Uzun and Bilgili 2011; Unal *et al.* 2011; Yalcin *et al.* 2011; Bozdogan 2012; Bozdogan *et al.* 2012). Sewage sludge can be used both as an organic fertilizer and growing media in ornamental plant cultivation (Apaolazaa *et al.* 2005; Arikan and Ozturk 2005; Cetinkale Demirkan *et al.* 2017). These previous studies revealed that sewage sludge could both be used alone and in mixtures with the other growing media at different ratios. In this way, vast amounts of sewage sludge can be reused in an economic and sustainable fashion. There are previous studies carried out with the mixture of sewage sludge and soils or other growing media in other plant species. But there has been no research on the use of sewage sludge in snowdrop cultivation. Snowdrop is a type of bulbous plant that is resistant to harsh conditions. This study was carried out to investigate the potential use of sewage sludge as a growing medium for Taurus snowdrops.

## EXPERIMENTAL

The study was conducted in the open fields of Architecture and Design Faculty of Çanakkale Onsekiz Mart University between 17$^{th}$ January 2017 and 26$^{th}$ May 2017 to determine potential use of sewage sludge in Taurus snowdrop (*Galanthus elwesii* Hook. f.) cultivation. Taurus snowdrop bulbs to be used in the experiments were supplied from a private company (Yasemin Tarım, İzmir, Turkey) exporting natural flower bulbs. Sewage sludge was supplied from Canakkale, Kepez Wastewater Treatment Plant. Domestic wastewater (yellow water, brown water, and grey water) was treated in this wastewater treatment plant. The wastewater treatment plant treated domestic wastewater with physical and biological methods. After the treatment processes, sewage sludge was formed together with treated water. Sewage sludge that had been formed in cake slice forms was sun-dried in an open field over plastic covers in June and August.

Bulbs with a circumference of 4 cm were free of course debris; healthy, plump, and well-appearing bulbs were selected. Before planting, bulbs were kept in 1% Captan and 0.5% Mancozeb (Koruma, Kocaeli, Turkey) solution for 20 min; then they were kept in plastic boxes for decanting and drying in a cool shady place. Sun-dried sewage sludge was

fragmented and crumbled into small particles and mixed in volume with soil at different ratios. Growing media were arranged as follows: 100% soil (GM1), 25% sewage sludge+75% soil (GM2), 50% sewage sludge+50% soil (GM3), 75% sewage sludge+25% soil (GM4), and 100% sewage sludge (GM5). Resultant growing media mixtures were placed into 15-L plastic pots (72 × 50.5 × 15.5 cm). Snowdrop bulbs were planted into growing media pointed side up on 17th January 2017. Twelve bulbs were planted into each pot (plot). Experiments were conducted in randomized plots in a design with 3 replications. Bulbs were irrigated right after planting and irrigations were performed later based on precipitation regime of the region. Weeds were manually removed from the pots. Meteorological data (minimum temperature, maximum temperature, average temperature, average relative humidity, precipitation) were received from the Canakkale Meteorological Station. Drainage effluents were sampled from the growing media 3 times in a month interval. The electrical conductivity (EC) and pH (AD12 pH/Temp Tester, Adwa Instruments, Szeged, Hungary) of drainage effluents were measured. Root length, bulb diameter, bulb weight, number of bulblets, bulblet diameter, bulblet weight, number of leaves, leaf length, leaf width, leaf thickness, pedicle length, pedicle diameter, fruit diameter, flower ratio and fruit ratio were measured. An analysis of variance (ANOVA), Duncan multiple comparison test ($P \leq 0.05$), and Pearson correlation test were performed with SPSS 26 (IBM SPSS Statistics, Chicago, IL, USA) statistics program.

In the research site, daily average temperature, minimum-maximum temperature, average relative humidity, and precipitation values are presented in Fig. 1. Temperatures fell below 0 °C for 4 days in January and 3 days in February. The lowest temperature was measured as -3.1 °C on 28th January 2017 and the maximum temperature was measured as 30.7 °C on 14th May 2017. Daily average relative humidity throughout the experiments varied between 45.6% to 90.7%.

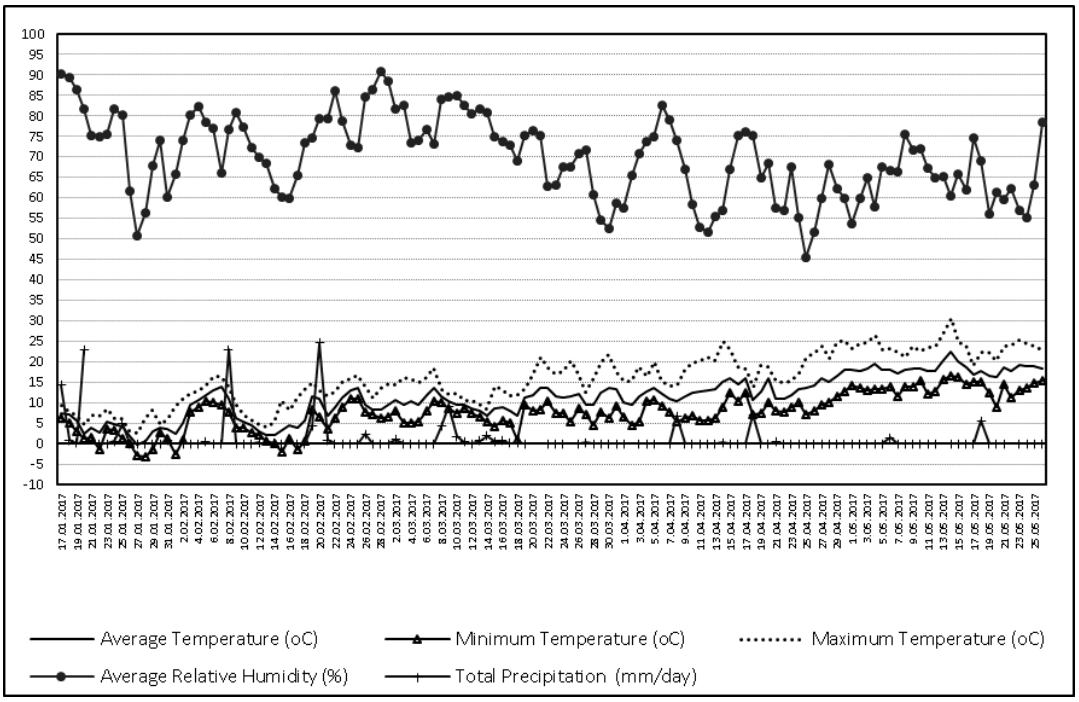


**Fig. 1.** Climate data of the research site

## RESULTS AND DISCUSSION

Snowdrop growth and development were not negatively influenced by the low and high temperatures experienced in this study. Total precipitation was measured as 69.1 mm at the end of the first month, 53.7 mm at the end of the second month, 8.1 mm at the end of the third month, and 9.3 mm at the end of the fourth month.

There were differences in pH and EC values of drainage effluents taken from growing media in 3 different periods (Fig. 2). Decreasing pH values were observed with increasing sewage sludge ratios. There was an increase in pH values at the end of the second month and a decrease at the end of the third month. The differences in pH values measured in 3 periods were attributed to sewage sludge ratios and daily precipitations. At the end of the first month, the greatest pH value (8.06) was observed in GM1 media containing only soil, and the lowest pH value (6.46) was observed in GM5 media containing only sewage sludge. Increasing EC values were observed with increasing sewage sludge ratios. The greatest EC value in all 3 periods was observed in GM5 media containing 100% sewage sludge. Akin and Kahraman (2018) used 0%, 25%, 50%, 75%, and 100% sewage sludge in ornamental cabbage culture and reported decreasing pH and EC values in time but increasing EC values with increasing sewage sludge ratios. Grigatti *et al.* (2007) experimented with 0%, 25%, 75%, and 100% sewage sludge ratios and reported increasing EC and pH values with increasing sewage sludge ratios. Unal *et al.* (2011) also reported increasing pH and EC values with increasing sewage sludge ratio in white lily culture. Ostos *et al.* (2008) reported greater EC and pH values for 40% sewage sludge+60% peat mixture than the peat treatment. Present findings on pH and EC comply with those earlier reports.

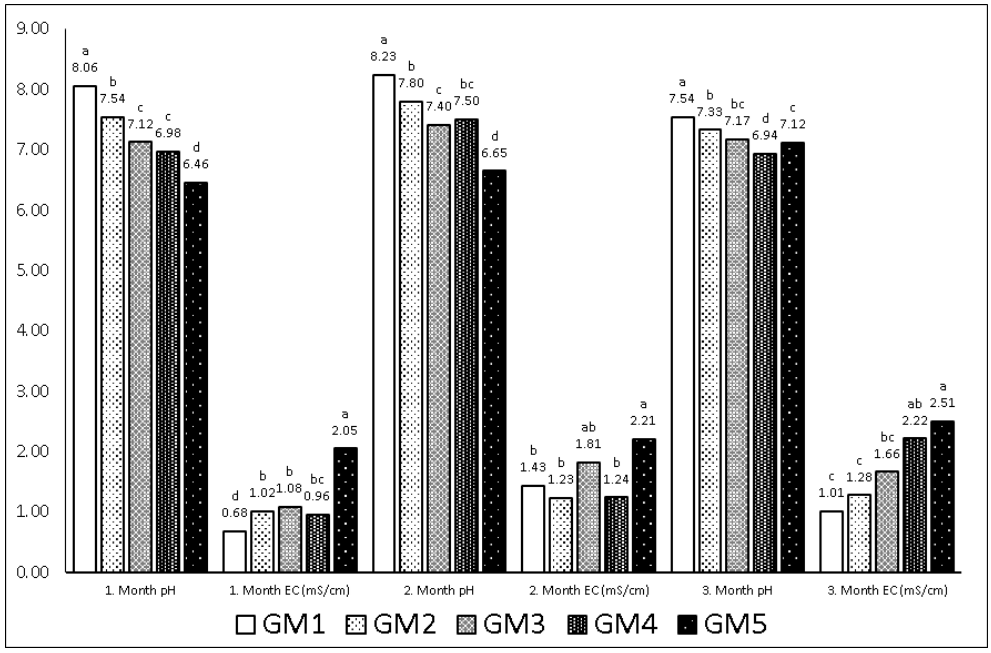


**Fig. 2.** The EC and pH values of drainage water from growing media

The growing media did not have significant effects on root length, bulb diameter, and bulb weight (Fig. 3). Root length ranged from 8.06 cm (GM2) to 11.86 cm (GM4), bulb diameter varied between 16.78 mm (GM5) and 18.53 mm (GM3), and bulb weight

was between 2.74 g (GM2) and 6.33 g (GM4). Yildirim *et al.* (2016) experimented with different growing media and deficit irrigation treatments for Taurus snowdrop plants and reported the greatest root length and bulb weights for peat+perlite and coconut peat media and for full irrigation (100%) treatment without any water deficits. Present root lengths were smaller, but bulb weights were greater than the values reported by Yildirim *et al.* (2016). Akat *et al.* (2015) indicated that increasing sewage sludge doses did not have significant effects on root length of *Limonium* plants and reported the greatest root length for 50% sewage sludge media. Akin and Kahraman (2018) also reported insignificant effects of different sewage sludge ratios on root lengths. In the present study, increasing sewage sludge ratios also did not yield significant differences in root length of Taurus snowdrop plants. Cetinkale Demirkan *et al.* (2017) tested soil, stabilized sewage sludge+soil (1:1), fish waste+soil (1:1), and coal slag+soil (1:1) mixture for *Matthiola incana* 'Iron Rose' culture and obtained the greatest root length from 50% stabilized sewage sludge+50% soil mixture. Grigatti *et al.* (2007) grew *Begonia semperflorens*, *Mimulu*s spp., *Salvia splendens* "Maestro", and *Tagetes patula* species in 0%, 25%, 75%, and 100% sewage sludge media and obtained the greatest weight gain from 25% and 50% sewage sludge media. Akin and Kahraman (2018) obtained the greatest weight in ornamental cabbage plants from 25% and 100% sewage sludge media. In the present study, the greatest bulb weight (Fig. 4) was obtained from 75% sewage sludge media (GM4).

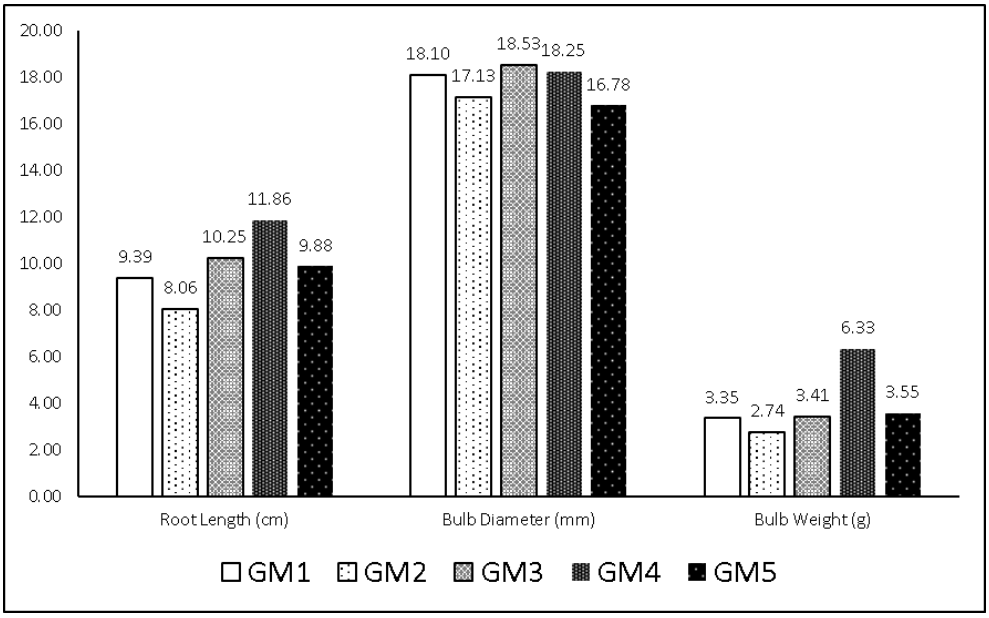


**Fig. 3.** Effects of growing media on root length, bulb diameter, and bulb weight

The differences in number of bulblets in various growing media were not found to be significant. The number of bulblets varied between 1.0 and 1.33. However, there were significant differences in bulblet diameter and bulblet weight of the growing media. There were two statistical groups for bulblet diameter. The greatest bulblet diameter was obtained from the group including GM1, GM2, GM3, and GM4 media. The lowest bulblet diameter (10.96 mm) was obtained from GM5 media. The greatest bulblet weight (2.17 g) was obtained from GM4 media.

While growing media did not have significant effects on number of leaves, leaf length, and leaf width, it did have significant effects on leaf thickness (Fig. 5). The greatest

leaf thickness (0.90 mm) was obtained from GM4 media (75% sewage sludge). The number of leaves ranged between 3.14 and 4.38, leaf lengths were between 7.30 and 9.25 cm, and leaf widths were between 9.66 and 11.63 mm. Akat *et al.* (2015) reported insignificant effects of increasing sewage sludge doses on number of leaves in *Limonium* plants and obtained the maximum number of leaves from 50% and 75% of sewage sludge ratios. The results from this study agree with earlier reports.

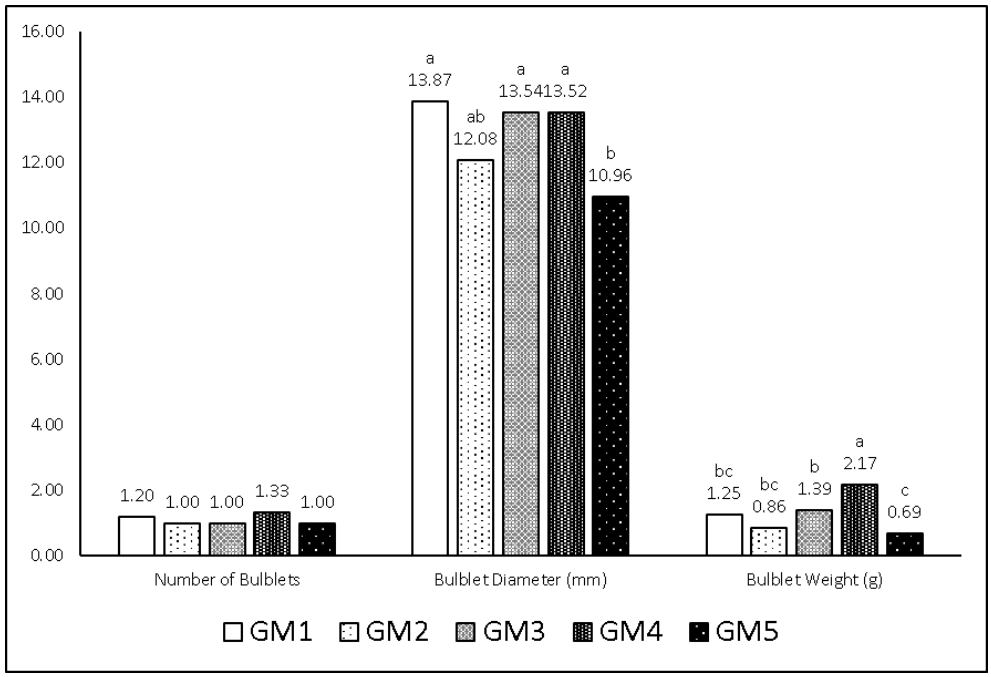


**Fig. 4.** Effects of growing media on bulblet characteristics

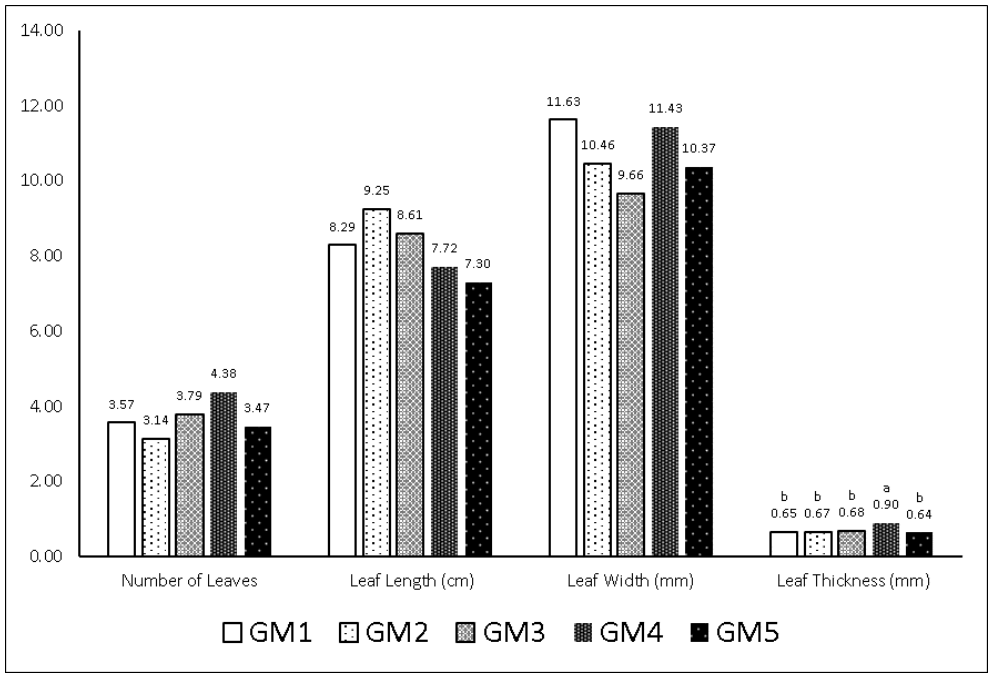


**Fig. 5.** Effects of growing media on leaf characteristics

The greatest values were obtained from 50% (GM3) and 75% (GM4) use of sewage sludge media. Yildirim *et al*. (2016) experimented with different growing media and deficit irrigations in Taurus snowdrop culture and reported greater plant heights than the present study. Planting density and growth media volume per bulb may result in such differences in plant heights. Ostos *et al.* (2008) indicated that sewage sludge increased plant height and weight of *Pistacia lentiscus* L. plants. Grigatti *et al.* (2007) tested with 0%, 25%, 50%, 75%, and 100% sewage sludge ratios and reported significant differences in plant heights of *Begonia semperflorens*, *Mimulus* spp., *Salvia splendens* "Maestro", and *Tagetes patula* species and obtained the greatest value from use of 25% sewage sludge media. Similar findings were observed in the present study regarding leaf length. The maximum leaf length was obtained from 25% sewage sludge media (GM2). Yon and Kahraman (2017) used 50% coconut fiber+50% soil, 50% sewage sludge+50% soil, 25% sewage sludge+75% soil, 25% wood chip+75% soil, 50% wood chips+50% soil, 25% hazelnut husk+75% soil, and 50% hazelnut husk+50% soil mixtures for Primrose culture. Researchers reported insignificant differences in number of leaves and leaf lengths from various growing media and die outs were reported in the fourth week in sewage sludge mixtures.

The effects of growing media on pedicle length, pedicle diameter, and fruit diameter were not found to be significant (Fig. 6).

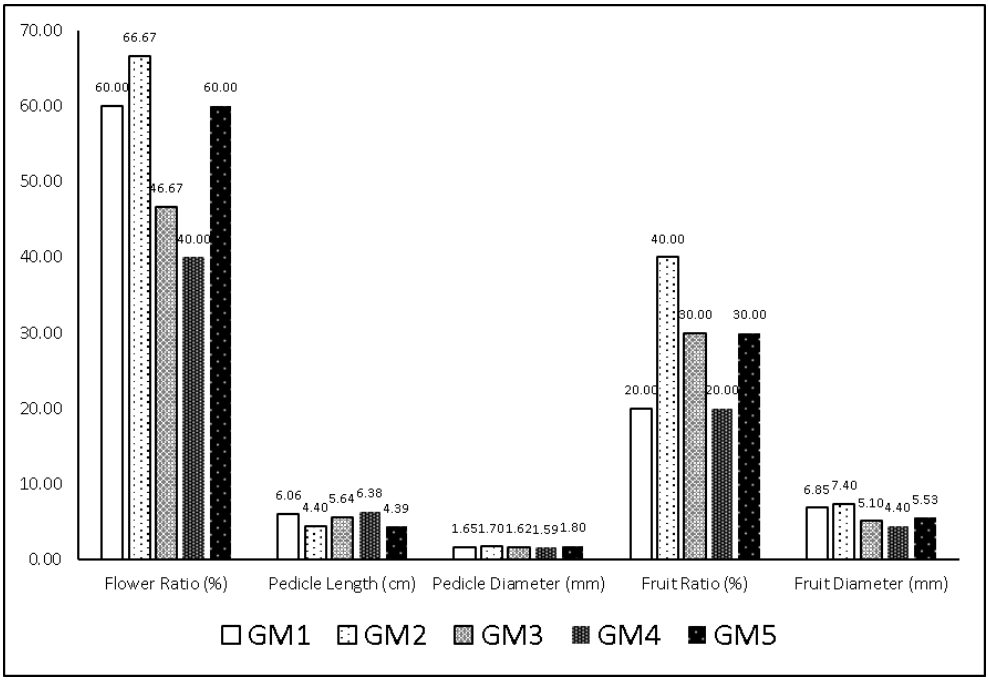


**Fig. 6.** Effects of growing media on flower and fruit characteristics

Pedicle lengths were 4.39 to 6.38 cm, pedicle diameters were 1.59 to 1.80 mm, and fruit diameters were 4.40 to 7.40 mm. The differences in flower and fruit ratios were not found to be significant. The GM2 (25% sewage sludge+75% soil) had a greater flower ratio (66.7%) and fruit ratio (40%) than the other growing media. Akat *et al.* (2015) also reported similar effects of different sewage sludge doses on number of flowers, pedicle length, and pedicle thickness of *Limonium* plants and reported the highest number of flowers for 50% sewage sludge dose and the greatest pedicle length for 75% sewage sludge ratio. Cetinkale

Demirkan *et al.* (2017) reported the most pedicle length and pedicle thickness of *Matthiola incana* 'Iron Rose' for 50% stabilized sewage sludge+50% soil mixture. Yon and Kahraman (2017) indicated that different waste materials influenced the number of flowers in primrose and reported the greatest number of flowers at the end of four-week growth period for 50% wood chips+50% soil mixture. Grigatti *et al.* (2007) obtained the maximum number of flowers in *Begonia semperflorens*, *Mimulus* spp., *Salvia splendens* "Maestro", and *Tagetes patula* species from the 25% sewage sludge containing media. These studies show that sewage sludge ratios had different effects on the parameters of flower and pedicle.

Bulb diameter positively correlated with bulb weight ($r = 0.955$, $p = 0.01$), root length ($r = 0.383$, $p = 0.05$), and leaf thickness ($r = 0.329$, $p = 0.05$). Root length and leaf thickness increased with increasing bulb weights. There were also positive correlations between leaf length and pedicle length at 99% confidence ($r = 0.631$). Low positive correlations were observed between root length and leaf length ($r = 0.368$, $p = 0.05$), and there were week positive correlations between number of bulblets and leaf width.

Apaolazaa *et al.* (2005) indicated that sewage sludge with 30% coconut fiber or wood chips was more sustainable without any nutrient deficiency and toxicity symptoms for *Pinus pinea*, *Cupressus sempervirens*, and *Cupressus arizonica*. Ozdemir *et al.* (2005) reported decreasing C/N ratios with increasing sewage sludge doses and indicated that sewage sludge brought soil physical and chemical properties to desired levels. The best results for plant growth performance were achieved with the mixtures including 30% and 50% sewage sludge in *Cupressus macrocarpa* 'Gold Crest' cultivar. Bozdogan *et al.* (2012) reported that sewage sludge mixtures did not have any negative effect on growth and development of *Cynodon dactylon* and *Alyssum maritimum*. Cetinkale Demirkan *et al.* (2017) indicated that soil+sewage sludge and soil+fish waste mixtures could be used as growing media in *Matthiola incana* 'Iron Rose' culture and reported the best growth and development for the media with sewage sludge. Yon and Kahraman (2017) reported that primrose plants died in the fourth week in mixtures with 25% and 50% sewage sludge, the plants maintained steady growth in the other mixtures. Zawadzinska and Salachna (2018) stated that plants grown in the sewage sludge and straw mix had longer shoots and more flowering for Ivy pelargonium. Akin and Kahraman (2018) indicated that ornamental cabbage could be grown in all media with different sewage sludge doses.

## CONCLUSIONS

1. The findings from this study revealed that Taurus snowdrops could reliably be grown in sewage sludge media without any damage of pH and EC on plants.
2. Regarding root length, bulb diameter, bulb weight, number of bulblets, bulblet diameter, and bulblet weights, 75% sewage sludge+25% soil should be used for Taurus snowdrop culture.

Thus, the disposal of sewage sludge becomes easier. However, heavy metal accumulations should always be monitored, and the values should not exceed threshold values. Relevant measurements and inspections should continuously be performed and when the limit values are exceeded, sewage sludge treatment should be terminated.

## ACKNOWLEDGMENTS

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