

Rooting and Growth of *Chrysanthemum morifolium* after Cutting in the Media Containing Blast Furnace Slag

Young-Sun Kim ^{*} and Bon-Soon Ku 

Department of Smart Horticulture, Daegu University, Gyeongsan 38453, Korea

* Correspondence: im0sunkim@daegu.ac.kr

Abstract: This study was conducted to investigate the effects of cutting media blended with blast furnace slag (BFS) and commercial substrate (CS) on their physicochemical properties and the growth of chrysanthemum (*Chrysanthemum morifolium*) cutting. pH and bulk density of cutting media blending BFS were higher than those of CS, while electrical conductivity (EC) was lower. The correlation coefficient between BFS blending ratio and the pH and bulk density of media was significantly positive ($p \leq 0.01$). As compared to CS, the root length and root dry weight in CS:BFS = 1:1 treatment were increased by 54.7% and 76.2%, respectively. The root length and dry weight in the CS:BFS = 1:1 treatment were similar to those of the perlite treatment. These results indicated that the blend of BFS with CS in the chrysanthemum cutting substrate significantly enhanced the root growth of chrysanthemum cuttings, and their optimal ratio was found to be 1:1 (v/v).

Keywords: Blast furnace slag (BFS), Bulk density, Chrysanthemum, Root dry weight, Root length

<https://doi.org/10.5338/KJEA.2026.45.02>

Agric. Environ. Sci. 2026, 45, 12-19

Received: November 1, 2025

Revised: November 21, 2025

Accepted: January 11, 2026

Published: March 17, 2026

Online ISSN: 2233-4173

Print ISSN: 1225-3537



Check for updates

© The Korean Society of Environmental Agriculture 2026



This is an Open Access article distributed under the terms of the Creative Commons Attribution Non-Commercial License (<https://creativecommons.org/licenses/by-nc/3.0/>) which permits unrestricted non-commercial use, distribution, and reproduction in any medium, provided the original work is properly cited.

Introduction

Chrysanthemum (*Chrysanthemum morifolium*), a perennial plant belonging to the Asteraceae family, is widely utilized as cut flowers, potted plants, and for ornamental landscaping. According to statistics from the National Institute of Horticultural and Herbal Science (NIHS), in 2023, the cultivation area for chrysanthemums reached 342 ha, with sales amounting to 4.9 billion KRW, establishing it as one of the major export crops within the floricultural industry. Propagation of chrysanthemums is predominantly achieved through vegetative reproduction using cuttings. This method typically involves two main approaches: conventional propagation, where cuttings are initially grown in a nursery environment before transplanting, and direct field planting, where cuttings are transplanted directly into the main cultivation area without an intermediate nursery phase. However, the quality of chrysanthemum seedlings produced via cuttings is highly influenced by the nursery environment and management conditions, which critically impacts the initial establishment rate of seedlings and subsequent productivity after transplanting [1].

Key factors determining the characteristics of chrysanthemum cuttings include the growth status of the mother plant, the inherent characteristics of the cuttings themselves, environmental conditions during the cutting process, methods of rooting hormone treatment, and the cutting medium [2-6]. Among these, the selection of an optimal cutting medium is particularly critical, as it directly influences the initial rooting and subsequent root development by providing essential water and air to the cuttings [7]. Cutting media commonly utilize materials such as peat moss or cocopeat to ensure adequate water supply, alongside perlite to facilitate oxygen delivery and drainage. These raw materials are often combined in carefully proportioned mixtures to create substrates that effectively mitigate the limitations of individual components [1]. Therefore, identifying a medium that offers superior water retention and aeration properties is a paramount factor in determining the overall growth and quality of chrysanthemum seedlings post-cutting [1].

Given that most raw materials used for cutting media and potting substrates are heavily reliant on imports, research efforts are being directed towards identifying viable alternatives or strategies to reduce their usage. Previous researches have investigated various materials such as hydrogel (a superabsorbent polymer), scoria, and sand as potential replacements for conventional potting substrate components [8, 9]. Among these, sand offers excellent drainage properties and can enhance soil porosity when incorporated into substrate mixtures, thus making it a plausible candidate for cutting medium. However, caution is warranted when utilizing sand, as river sand mining can raise environmental concerns, and sea sand may introduce salinity issues due to seawater. In light of these considerations, blast furnace slag, possessing characteristics similar to sand, presents a promising alternative [10].

Blast furnace slag (BFS) is a byproduct generated during steel production, manufactured by rapidly cooling molten slag and then finely pulverizing it [10]. This material notably contains calcium carbonate [10]. BFS has been widely utilized as a substitute for sand or cement, and its recycling contributes to the reduction of carbon emissions [11]. Historically, BFS has been predominantly used as a construction material [10, 11]. Recently, patents have emerged proposing its use as a sand-substitute in horticultural applications, such as for turfgrass planting soils or topdressing material; however, research on its application as an agricultural material remains limited. Given that blast furnace slag (BFS) exhibits sand-like properties, not only its agricultural utilization but also research on its safety is essential for its use as a raw material in seedling propagation media. Chrysanthemum cuttings, whose cut surfaces are directly exposed to BFS during the propagation process, can therefore serve to verify its safety for plants and to determine its potential as a sand substitute in propagation substrates. Therefore, this study aims to evaluate the potential of BFS as a raw material for cutting media. Specifically, we investigated the physicochemical properties of cutting media mixed with commercial substrate (CS) and BFS, and subsequently examined the growth changes of 'Baekgang' chrysanthemums (*C. morifolium*) propagated in these mixed media.

Results and Discussion

Physicochemical properties of mixed media containing blast furnace slag

The physicochemical characteristics of the mixed media, incorporating different blending ratios of BFS with CS, were investigated (Table 1). The pH of the mixed media ranged from 4.94 to 8.70, with CS exhibiting an acidic pH of 4.94 and BFS showing an alkaline pH of 8.14. The electrical conductivity (EC) of the mixed media varied from 0.01 to 0.61 dS/m; CS recorded an EC of 0.61 dS/m, whereas BFS had an EC of 0.32 dS/m. Furthermore, the bulk density of the mixed media ranged from 0.13 to 1.12 g/cm³, with CS showing 0.15 g/cm³ and BFS registering 1.12 g/cm³. Correlation analysis between the BFS blending ratio and the physicochemical properties of the mixed media revealed a significant positive correlation for both pH ($r=0.928^{**}$, $p\leq 0.01$) and bulk density ($r=0.988^{**}$, $p\leq 0.01$). Conversely, EC showed a significant negative correlation ($r=-0.894^{**}$, $p\leq 0.01$) with the BFS blending ratio. These findings align with reports by Kim et al. [12], who demonstrated that the physicochemical properties of sand mixed with soil amendments vary depending on the amendment's characteristics. Our study similarly observed corre-

Table 1. Physicochemical properties of media blended with blast furnace slag (BFS)

Treatments ¹⁾	pH	EC (1:5, v:v)	Bulk density
	(1:5)	dS/m	g/cm ³
CS:BFS = 1:0	4.94e ²⁾	0.61a	0.15g
CS:BFS = 1:1	6.10d	0.36d	0.75d
CS:BFS = 2:1	6.16d	0.48c	0.54e
CS:BFS = 3:1	6.18d	0.50b	0.42f
CS:BFS = 0:1	8.14b	0.32e	1.12a
CS:BFS = 1:2	8.07bc	0.29f	0.90c
CS:BFS = 1:3	7.98c	0.25g	1.00b
Perlite	8.70a	0.01h	0.13g
Correlation ³⁾	0.928**	-0.894**	0.988**

¹⁾ CS and BFS mean commercial substrate and blast furnace slag, respectively.

²⁾ Means with the same letters within a column are not significantly different by Duncan's multiple range test $p \leq 0.05$ level.

³⁾ ** represent a significance at the 0.01 probability level, for correlation coefficient between BFS blending ratio and physicochemical factor of media.

sponding changes in the pH, EC, and bulk density of the mixed media with increasing BFS incorporation. Acidic soil amendments such as peat, peat moss, and coir pith resulted in acidic soil pH when mixed with soil, whereas zeolite, a weakly alkaline soil amendment, caused the soil pH to become alkaline after mixing [12]. In this study, BFS, an alkaline material, was observed to increase the pH of the CS to an alkaline range when mixed. This change was attributed to the influence of the added BFS, showing a similar trend to the results reported by Kim et al. [12].

Rooting and growth of chrysanthemum cuttings after cutting

The rooting and growth parameters of chrysanthemum cuttings were evaluated in mixed media with varying BFS and CS ratios (Table 2). Chlorophyll content ranged from 4.1 to 4.4 mg/100 cm², with the highest content observed in the CS:BFS = 1:0 treatment (only CS treatment) and the lowest in the CS:BFS = 2:1 treatment. This observation is attributed to the presence of essential nutrients for seedling growth within the CS [13]. Specifically, nutrients such as nitrogen, magnesium, sulfur, and iron, which are supplied by CS, are known to significantly enhance chlorophyll accumulation in plant foliage [14].

The leaf number ranged from 6.9 to 8.4 leaves per plant, with the highest count observed in the only CS treatment and the lowest in the CS:BFS = 1:2 treatment. When compared to the only CS treatment, no statistically significant differences were observed in all other treatments except for the CS:BFS = 1:2 ratio. Leaf length and leaf width ranged from 4.0 to 4.3 cm and 2.3 to 2.5 cm, respectively. For both leaf length and width, no statistically significant differences were found between the only CS treatment and any of the other treatment groups.

Root length ranged from 4.7 to 8.0 cm, with the longest roots observed in the CS:BFS = 1:1 treatment and the shortest in the CS:BFS = 1:2 treatment. Compared to only CS treatment, root length of CS:BFS = 1:1 treatment was increased by 54.7%. Yoo and Roh [1] reported that chrysanthemum cuttings rooted more easily in substrate formulations with a higher air-filled porosity, facilitating optimal oxygen supply and carbon dioxide diffusion, which is critical for root development.

The dry weights of the shoot and root parts ranged from 0.19 to 0.24 g/plant and 0.010 to 0.031 g/plant, respectively. The highest shoot dry weight was observed in the only CS treatment, whereas the highest root dry weights were found in the CS:BFS = 1:1 and CS:BFS = 0:1 (only BFS) treatments. It is inferred that shoot growth was primarily influenced by the nutrient content within the substrate. This was supported by the only CS treatment, which not only yielded the highest shoot dry weight but also exhibited the highest EC (0.61 dS/m) among all treatments, indicating a rich nutrient supply (Table 1). Therefore, the only CS treatment, which was notably nutrient-rich, likely had a significant impact on the shoot growth of chrysanthemum cuttings. Furthermore, a negative correlation was observed between the amount of BFS incorporated and the shoot growth of chrys-

Table 2. Rooting and cut flower growth of chrysanthemum in media blended with blast furnace slag (BFS)

Treatments ¹⁾	Chlorophyll	No. of leaves	Leaf length	Leaf width	Root length	Shoot dry weight	Root dry weight
	mg/100cm ²	ea/plant	cm	cm	cm	g/plant	
CS:BFS = 1:0	4.4a ²⁾	8.4a	4.0a	2.5a	5.2bc	0.24a	0.0175bc
CS:BFS = 1:1	4.2ab	8.3ab	4.2a	2.5a	8.0a	0.21b	0.0308a
CS:BFS = 2:1	4.1b	7.8ab	4.0a	2.3a	7.0ab	0.21b	0.0267ab
CS:BFS = 3:1	4.2ab	7.4ab	4.1a	2.5a	5.2bc	0.20b	0.0100c
CS:BFS = 0:1	4.3ab	7.5ab	4.1a	2.5a	5.4bc	0.19b	0.0300a
CS:BFS = 1:2	4.4ab	6.9b	4.1a	2.5a	4.7c	0.21b	0.0175abc
CS:BFS = 1:3	4.3ab	7.8ab	4.3a	2.5a	6.9abc	0.20b	0.0171abc
Perlite	4.2ab	7.6ab	4.1a	2.5a	6.3abc	0.21b	0.0217abc
Correlation ³⁾	-0.018 ^{NS}	-0.322 ^{NS}	0.258 ^{NS}	0.042 ^{NS}	0.036 ^{NS}	-0.576 ^{**}	0.304 ^{NS}

¹⁾ CS and BFS mean commercial substrate and blast furnace slag, respectively.

²⁾ Means with the same letters within a column are not significantly different by Duncan's multiple range test $p \leq 0.05$ level.

³⁾ ^{NS} and ^{**} represent no significant difference and a significance at the 0.01 probability level, for correlation coefficient between BFS blending ratio and plant growth factor.

anthemum cuttings ($r = -0.576^{**}$, $p \leq 0.01$), suggesting that an increased BFS blending ratio resulted in a reduction of the nutrient content derived from CS.

The highest root dry weights were observed in the CS:BFS=1:1 and CS:BFS=0:1 (100% BFS) treatments. When compared to the perlite treatment, which is conventionally used by farmers for direct cuttings, the CS:BFS=1:1 and CS:BFS=0:1 treatments exhibited favorable rooting and root growth, although they were not significantly different (Fig. 1). As compared to only CS treatment, root dry weight of CS:BFS = 1:1 treatment was increased by 76.2%. Generally, root growth is primarily attributed to the physical properties of the medium. Thus, successful rooting of chrysanthemum cuttings is a crucial determinant not only for overall seedling growth but also for quality, significantly influencing the early establishment of the seedlings [1].

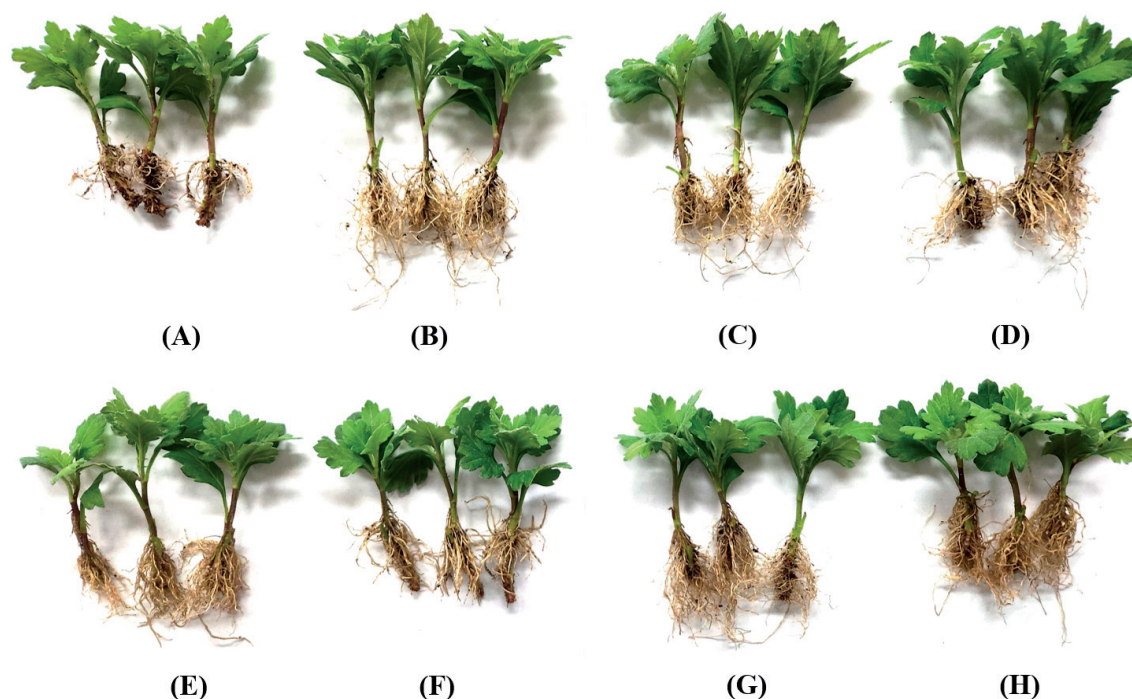


Fig. 1. Root growth of *Chrysanthemum morifolium* in media blended with blast furnace slag (BFS). Treatments were as follows. CS:BFS=1:0 (A), CS:BFS=1:1 (B), CS:BFS=2:1 (C), CS:BFS=3:1 (D), CS:BFS=0:1 (E), CS:BFS=1:2 (F), CS:BFS=1:3 (G), and perlite (H).

Table 3. Correlation coefficient among growth factors of chrysanthemum in media blended with CS and BFS

Growth factor	Chlorophyll	No. of leaves	Leaf length	Leaf width	Root length	Shoot dry weight	Root dry weight
Chlorophyll	1.000	0.415	-0.180	-0.094	-0.084	0.479*	-0.387
No. of leaves		1.000	-0.063	-0.390	0.360	0.327	-0.131
Leaf length			1.000	0.293	0.042	-0.352	-0.091
Leaf width				1.000	0.191	0.162	0.123
Root length					1.000	-0.081	0.446*
Shoot dry weight						1.000	-0.078
Root dry weight							1.000

* represents a significance at the 0.05 probability level.

Pearson correlation analysis was performed to identify the relationships among various growth factors of the chrysanthemum cuttings (Table 3). The chlorophyll content of the cuttings showed a positive correlated with shoot dry weight ($r=0.479^*$, $p\leq 0.05$), and root length a positive correlation with root dry weight ($r=0.446^*$, $p\leq 0.05$). While increased root development generally enhances shoot growth in plants [8], there was no significantly different correlations between rooting and shoot growth in chrysanthemum cuttings, because nutrient supply is minimal prior to rooting during the seedling period [15]. Consistent with previous research [15], this study also showed no significant correlation between rooting and shoot growth. It is thus inferred that the factors primarily influencing shoot growth are attributed to the nutrient content of the cutting medium (Tables 1, 2). This is generally because both shoot growth and chlorophyll content in the foliage are significantly affected by the absorption of supplied nutrients during plant development [16].

Root growth parameters, such as root length and root dry weight of chrysanthemum cuttings, are primarily determined by the porosity of the medium [15]. In this study, a positive correlation was observed between the BFS application rate and bulk density, suggesting that an increased BFS application rate would lead to a decrease in porosity [12]. This is because porosity, determined by the sum of capillary porosity and air-filled porosity, varies depending on the type and characteristics of the material [12]. A Pearson correlation analysis between bulk density and root growth such as root length ($r=0.049$, $p=0.820$) and root dry weight ($r=0.348$, $p=0.096$) in this study showed no significant difference, indicating that total porosity has a negligible effect on root growth during chrysanthemum cutting. Kim and Kim [17] reported that an increase in the air-filled porosity of the substrate used for chrysanthemum cultivation led to enhanced rooting. This suggests that the air-filled porosity of the medium significantly influences rooting success.

Conclusion

This study investigated the physicochemical properties of mixed substrates containing CS and BFS, along with the growth changes in 'Baekgwang' chrysanthemum (*C. morifolium*) cuttings, to evaluate the potential of BFS as a raw material for cutting media. Correlation analysis between the BFS blending ratio and the physicochemical properties of the mixed media were significantly positive correlated ($p\leq 0.01$) with pH and bulk density as the BFS ratio increased, while electrical conductivity (EC) negative correlation ($p\leq 0.01$). Compared to the only CS treatment (CS:BFS = 1:0), the CS:BFS = 1:1 treatment resulted in a substantial increase in root length and dry weight of cuttings, by 54.7% and 76.2%, respectively. Furthermore, when compared to the conventional perlite treatment, the CS:BFS = 1:1 mixture exhibited similar growth characteristics such as root length and dry weight. In summary, these results indicate that mixing CS and BFS in a 1:1 ratio is most effective in promoting root growth of chrysanthemum cuttings. Therefore, BFS holds significant potential as a raw material for chrysanthemum cutting media and is expected to be widely utilized across various agricultural and landscaping propagation.

Materials and Methods

Materials

This study was conducted for two months, from September to October 2025, in a greenhouse dedicated to seedling propagation at Daegu University. Cuttings of chrysanthemum (*C. morifolium*) were provided by Farm A, located in Jeollabuk-do. The cultivar 'Baekgang' was used for propagation. To prevent excessive transpiration, two fully expanded leaves were retained on each cutting, and all other leaves were removed. Among the retained leaves, leaf blades exceeding 2 cm in length were cut in half, while those smaller than 2 cm were left intact. For the experimental substrates, CS (Seoul Bio Co., Ltd., Seoul, Korea) was purchased from an agricultural supply store. BFS was donated from Company B in Gyeonggi-do, and perlite by Company C in Jeollabuk-do. The bulk densities of the CS and BFS were measured as 0.15 g/cm³ and 1.12 g/cm³, respectively (Table 1).

Blending with CS and BFS

The experimental substrates were mixed by volume, taking into consideration the measured bulk densities of CS and BFS. The treatments were as follow: Treatment 1 (CS:BFS = 1:0, only CS), Treatment 2 (CS:BFS = 1:1), Treatment 3 (CS:BFS = 2:1), Treatment 4 (CS:BFS = 3:1), Treatment 5 (CS:BFS = 0:1, only BFS), Treatment 6 (CS:BFS = 1:2), Treatment 7 (CS:BFS = 1:3), and Treatment 8 (perlite).

Chrysanthemum Cutting Propagation

The mixed substrates for each treatment (CS and BFS mixtures) were filled into 12-cell plug trays (Zigpot12, Daeseung Co., Jeonju, Korea) at 100 mL per cell. To prevent disease occurrence, the filled trays were applied with a tebuconazole EC (tebuconazole 25%, Farmhannong, Seoul, Korea). Chrysanthemum cuttings of uniform size (6.5 ± 0.5 cm in length, 2.1 ± 0.2 mm in stem diameter) were prepared. The cuttings were dipped in 1000 mg/L indole-3-butyric acid (IBA; Duchefa Biochemie, Haarlem, Netherlands) dissolved in 1N KOH for 5 minutes. Subsequently, one cutting was inserted into each cell of the trays to a depth of 3 cm in the seedling propagation greenhouse at Daegu University.

An irrigation in the greenhouse was managed using an automatic misting system. Chrysanthemum cuttings were rooted on greenhouse benches under 50% shading, maintaining an average daytime temperature of $20 \pm 2^\circ\text{C}$ and a relative humidity of $80 \pm 10\%$. The misting irrigation schedule was as follows: until 14 days after sticking (DAS), misting occurred for 1 minute every 10 minutes from 7:00 AM to 7:00 PM. For 15 to 21 DAS, misting occurred for 1 minute every 10 minutes from 7:00 AM to 5:00 PM. The cutting propagation experiment was conducted for a total of three weeks, from September 23 to October 14, 2025.

Physicochemical properties of media and growth investigation of chrysanthemum cuttings

The mixed media were analyzed for pH, electrical conductivity (EC), and bulk density according to the standard analysis methods for growing media proposed by the Rural Development Administration (RDA) of Korea. For chrysanthemum cuttings in the mixed media, chlorophyll content, leaf number, leaf length, leaf width, root length, shoot dry weight, and root dry weight were investigated.

Chlorophyll content was measured using a chlorophyll meter (SPAD-501 plus, Minolta, Tokyo, Japan) by assessing the central area of the two longest leaves per plant. The measured SPAD values were converted to chlorophyll content using the method described by Kim and Kim [8]. Leaf number was determined by counting the total number of leaves with a leaf blade extended beyond 1 cm. Leaf length and leaf width were measured as the maximum length and width of the leaves, respectively. After the experiment, root length was measured by carefully separating the roots from the substrate to prevent breakage, washing them with tap water, placing the individual plants on a paper towel to remove excess water, and then measuring the longest root.

Shoot and root dry weights were measured after drying the samples in a dry oven (OF-W155, Daihan Scientific, Daegu, Korea) set at 70°C for 24 hours until a constant weight was achieved.

Statistical Analysis

Statistical analysis was performed using SPSS (ver. 29, IBM, NY, USA). Significant differences among treatment means were determined by Duncan's multiple range test. Additionally, Pearson correlation analysis was conducted to investigate the correlation between growth factors and BFS application rates.

Data Availability: All data are available in the main text or in the Supplementary Information.

Author Contributions: Y.-S. Kim conceived and designed the research, performed the statistical analysis, wrote the first manuscript, and revised the manuscript, provide critical feedback; B.-S. Ku led the growth experiment, and collected the data.

Notes: The authors declare no conflict of interest

Acknowledgments: This research was supported by the Regional Innovation System & Education (RISE) program through the Gyeongbuk RISE CENTER, funded by the Ministry of Education (MOE) and the Gyeongsangbuk-do, Republic of Korea.

Additional Information:

Supplementary information The online version contains supplementary material available at <https://doi.org/10.5338/KJEA.2026.45.02>
Correspondence and requests for materials should be addressed to Young-Sun Kim.

Peer review information Agricultural and Environmental Sciences thanks the anonymous reviewers for their contribution to the peer review of this work.

Reprints and permissions information is available at <http://www.korseaj.org>

References

1. Yoo Y, Roh Y (2012) Effects of cutting condition on growth of rooted cutting and cut flower in plug cutting of *Dendranthema grandiflorum* 'Baekma'. Korean Journal of Horticultural Science and Technology, 30(1), 13–20. <https://doi.org/10.7235/hort.2012.11071>.
2. Druege U (2000) Relation between nitrogen status, carbohydrate distribution and subsequent rooting of chrysanthemum cutting as affected by pre-harvest nitrogen supply and cold-storage. Annals of Botany, 85(5), 687–701. <https://doi.org/10.1006/anbo.2000.1132>.
3. Yoo YK, Roh YS (2009) Effects of cutting condition on rooting and growth of cut flower in plug cutting of *Dendranthema grandiflorum* 'Twnohakusen'. Flower Research Journal, 17, 256–262.
4. Woo JH, Shim YG, Han YY, Seo YJ, Kim CB, Choi KB, Kim KW (2000) Effect of plug cell size, rooting medium and shading duration on rooting and growth of *Dendranthema grandiflorum* 'Baegkwang' cutting. Journal of the Korean Society of Horticultural Science, 41, 292–296.
5. Shin HJ, Lee JM (1979) Effect of propagation method and growth regulator on the rooting of chrysanthemum cuttings. Journal of the Korean Society of Horticultural Science, 20, 111–116.
6. Hwang IT, Cho KC, Kim BS, Kim HK, Kim JG, Kim KS (2007) Effects of root substrate, preplanting nutrient charge and tray cell size on the quality and growth of chrysanthemum (*Dendranthema grandiflorum* L.) cuttings. Flower Research Journal, 15, 131–135.
7. Kim GH, Won EJ, Jeong BR (2006) Use of cellular glass foam (CGF) as a propagation medium of *Dendranthema grandiflorum* 'Backgwang' and *Euphorbia pulcherrima*. Flower Research Journal, 14(3), 186–190.
8. Kim Y, Kim H (2025) Seedling growth of lettuce and Chinese cabbage in substrates blending bottom ash derived after combusting a livestock compost. Korean Journal of Environmental Agriculture, 44, 239–245. <https://doi.org/10.5338/kjea.2025.44.25>.
9. Ro NY, Ko HC, Hur OS, Kang MJ, Oh SJ, Huh YC (2011) Rooting performance using cuttings and analysis of light and soil environmental characteristics for indoor plants of winter daphne (*Daphne odora* Thunb.). Journal of Bio-Environment Control, 20(4), 346–351.
10. Yang JH, Park JH (2017) Thermal characteristics of concrete fabricated with blast furnace slag subjected to thermal cycling condition.

- Journal of the Korean Recycled Construction Resource Institute, 5(4), 414–420. <https://doi.org/10.14190/JRCR.2017.5.4>.
11. Song K, Yang K, Lee B, Song J (2012) Carbonation characteristics of alkali activated blast-furnace slag mortar. Journal of the Korea Concrete Institute, 24(3), 315–322. <https://doi.org/10.4334/jkci.2012.24.3.315>.
 12. Kim YS, Ham SK, Lim HJ (2010) Change of soil physicochemical properties by mixed ratio of 4 type of soil amendments used in golf course. Korean Journal of Turfgrass Science, 24(2), 205–210.
 13. Choi JM, Shim CY, Chung HJ (2001) Effect of liming fertilization on changes of nutrient concentrations in rice-hull based media, crop growth and nutrient uptake of chrysanthemum. Journal of the Korean Society of Horticultural Science, 42(5), 553–556.
 14. Kim YH, Kim KS, Kim M (2001) The effect of the usage mixed organic fertilizer on turfgrass growth and chlorophyll content. Journal of the Korean Society of Agricultural Chemistry and Biotechnology, 44(2), 129–132.
 15. Oh W, Kim KS, Yoo YK (1998) Effects of air-filled porosity of rooting media on rooting and growth of chrysanthemum cutting. Journal of the Korean Society of Horticultural Science, 39(1), 92–97.
 16. Lee CW, Lee EW (1983) Growth and nutrient uptake as affected by ammonium sulfate and urea in the paddy rice. Journal of Korean Society of Crop Science, 28(4), 391–418.
 17. Kim SH, Kim KS (1999) Effects of irrigation frequency, particle size and depth of perlite medium on growth and flowering of *Dendranthema grandiflorum* grown on recycling system. Journal of the Korean Society of Horticultural Science, 17(3), 355–360.