Correlation between Cultivation Environment, Cropping System, and Quality Elements of Cut Flower and in *Dendranthema grandiflorum* 'Jinba'

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ABSTRACT

This study was conducted to analyze the correlation between cultivation environment, cropping system, and the quality of cut flower in autumn-winter season chrysanthemum 'Jinba', and to suggest the cultivation factors that can improve the quality of cut flower. It was examined for cultivation environment such as average day and night temperature, average day and night relative humidity, average day and night vapor pressure deficit (VPD), and integrated solar radiation of 4 farms planted in mid-October. Also, it was surveyed for cropping system such as cutting condition, growth period, irrigation method, soil chemical properties. Chrysanthemum 'Jinba' was harvested in order to investigate the quality of cutting of four farms, and then growth, chlorophyll content, and vase life of cut flowers were investigated. Based on these data, it was analyzed for the correlation between cultivation environment, cropping system, and quality of cut flower elements. In correlation between cultivation environment and quality of cut flower, the average night temperature showed a negative correlation with the growth of cut flower, and it was no correlation with other environmental factors. The vase life showed a negative correlation with the average day and night temperature and VPD, and a most positive correlation with the average day and night humidity. In correlation between cropping system and quality of cut flower, the cutting length, period of vegetative growth, daily irrigation amount, and total irrigation amount showed a less positive correlation, and leaf number of cutting and soil pH showed a most positive correlation with growth of cut flower. On the other hand, soil EC showed a less negative correlation, and days to flowering after light out showed a most negative correlation with growth of cut flower. The vase life of cut flower was not correlated with the cropping system factors.

Keywords: cultivation factor, cutting condition, growth period, irrigation method, soil chemical properties

Introduction

Standard chrysanthemums are used in funerals commonly in East Asia, including Korea, Japan and China. In particular, varieties such as 'Baekseon', 'Baekma' and 'Jinba' have been widely cultivated in Korea, and such varieties are domestically distributed, but a large amount of the domestically cultivated chrysanthemums is exported to Japan. The export amount of cut chrysanthemum was 287,198 kg in 2016, and 99.8% of them was exported to Japan. However, the

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amount is down by 14.0% from that in 2015 (333,929 kg) due to various reasons such as the rising cost of agricultural inputs, a weak Japanese yen, and rising competitors such as Vietnam, China, Indonesia, and Malaysia (KATI, 2017). To address such issues, it is necessary to produce and export cut chrysanthemum of high quality.

The quality of cut chrysanthemum is determined by the length and weight of cut flowers, flower width, the number of ray flowers, and flower neck length, and they are also affected by cultivation conditions and irrigation methods such as the quality of cuttings and rooted cuttings, the conditions of soil, light, temperature, and humidity (Hwang et al., 2007; Lee et al., 2009; Roh and Yoo, 2010; Yoo and Roh, 2012). Cut chrysanthemum grown in inadequate conditions can be damaged by diseases and insects such as white rust and western flower thrips (Yoo and Roh, 2014), and shows physiological disorders, such as open center and rosette, and poor growth and flowering (Yoo and Kim, 2004; Kim et al., 2009). In addition, the vase life of cut flowers is closely related to cultivation conditions. When 'Souvenir', a rose variety, was under supplementary lighting for 16 hours and at a relative humidity of 60%, compared to 24 hours of supplementary lighting, and 90% of relative humidity, its vase life was extended by 11 days (Mortensen and Fjeld, 1998). In the case of other cut rose varieties grown for export such as 'Antique Curl' and 'Beast,' relative humidity has a negative correlation with vase life in summer, and thus their vase life can be extended by controlling relative humidity (Yeon and Kim, 2016).

Jinba is an autumn-winter chrysanthemum variety and its flower is big and white. It is harvested from autumn to spring, and both sold in the domestic market and exported to Japan (Roh and Yoo, 2010). However, the quality of cut flowers has been reduced due to inadequate cultivation conditions and methods. Therefore, this study aimed to analyze the correlation between the cultivation conditions, cropping system, and quality elements of cut chrysanthemum Jinba, and identify cultivation factors that can improve their quality.

Materials and Methods

This study was conducted on 4 farms that grow cut chrysanthemum Jinba in Jeonju, Muan, and Haenam, and cuttings were grown in a growth cabinet using a cutting method in mid October.

Analysis of cultivation conditions

The cultivation conditions of 4 chrysanthemum farms were measured for 104 days from October 14 to January 26 using a data logger (Watchdog-1450, Spectrum Technologies Co. LTD., England), including average temperature, relative humidity and vapor pressure deficit (VPD) in the daytime (from 6 a.m. to 6 p.m.) and the nighttime, and daily integrated solar radiation during the research period.

Analysis of cultivation methods

The cultivation methods were also analyzed focusing on the followings: the conditions of cuttings in the 4 farms before cutting (the length of cuttings, the number of leaves, the diameter of cuttings); irrigation conditions during cultivation (daily irrigation amount, total irrigation amount); and growth periods (vegetative growth period, days to flowering after lights out, the number of days to flower after planting). In addition, to examine the chemical properties of soil, soil was sampled after harvesting cut flowers and the pH and EC of soil were tested using a soil analyzer (A-DF14 JG200, Jingu Scientific, Korea).

Assessment of the quality of cut flowers

Flowers were cut upon flowering in the 4 chrysanthemum farms, and the length of cut flowers, stem diameter, the number of leaves, the weight of cut flowers and flower width were measured. Using a chlorophyll meter (SPAD-502, Minolta, Japan), the content of chlorophyll in leaves was measured. After that, the flowers were cut into 70 cm, and put in a vase filled with 3 L of distilled water. The vase life of cut flowers was measured in a culture room (temperature: 25°C, humidity: 55%, light intensity: 1,000 lux) at the moment when the outmost petal or leaf began to wither.

Correlation and statistical analysis

ANOVA (Analysis of variance) was conducted on all the data collected in this study using IBM SPSS ver. 18.0, and the average values of individual factors were compared using DMRT (Duncan's multiple range test). The level of statistical significance was $p < .05$. Correlation between cultivation conditions and methods, and the quality of cut flowers was analyzed using Pearson's method.

Results and Discussion

Analysis of the cultivation conditions of chrysanthemum farms

The average temperature in the 4 chrysanthemum farms in the daytime and nighttime from October 14 to January 26 is as shown in Fig. 1. The average temperature in the daytime was 12.3~26.0°C in Farm A, 11.2~26.5°C in Farm B, 10.5~22.8°C in Farm C, and 9.8~26.8°C in Farm D. The temperature difference in Farm D was highest. The average temperature in the nighttime was 9.9~20.8°C in Farm A, 12.1~24.6°C in Farm B, 13.0~20.2°C in Farm C, and 7.6~24.5°C in Farm D. To induce flower bud differentiation in chrysanthemum Jinba flowers, the temperature should be maintained between 22 and 23°C (Roh and Yoo, 2010), but the temperature in Farm A was maintained at 17~18°C, lower than the recommended level. Between the flower bud differentiation stage and development stage, the temperature should be over 16~17°C, but the temperature in Farm B was maintained at 14~15°C, lower than the recommended level.

The average relative humidity in the 4 chrysanthemum farms in the daytime and nighttime is as shown in Fig. 2. The average relative humidity in the daytime was 32.2~86.9% in Farm A, 53.1~92.5% in Farm B, 45.5~87.8% in Farm C, and 43.0~92.5% in Farm D. In particular, the relative humidity in Farm D from late October was maintained at the lowest level

Figure 1. Comparison of average daytime (A) and nighttime (B) temperature of four farms during autumn and winter culture in cut chrysanthemum 'Jinba'.

among the 4 farms. The average relative humidity in the nighttime was 63.5~87.5% in Farm A, 65.8~93.0% in Farm B, 65.0~89.2% in Farm C, and 39.5~93.8% in Farm D, indicating that the relative humidity in the nighttime was higher than that in the daytime.

The average vapor pressure deficit (VPD) in the 4 farms in the daytime and nighttime is as shown in Fig. 3. The average VPD in the daytime was 0.2~1.8 kPa in Farm A, 0.2~1.3 kPa in Farm B, 0.2~1.3 kPa in Farm C, and 0.2~1.4 kPa in Farm D. The average VPD in the nighttime was 0.2~0.7 kPa in Farm A, 0.2~1.0 kPa in Farm B, 0.2~0.7 kPa in Farm C, and 0.1~1.6 kPa in Farm D. In an earlier study, it was found that the cut flowers of a standard chrysanthemum variety, Baekma, were grown well when the VPD in cultivation facilities was 0.4~0.8 kPa, and that the occurrence of diseases was suppressed (Yoo et al., 2016). In this study, the number of days when the VPD in Farm A in the early stage of growth in the daytime was over 1.0 kPa was relatively high, and the level decreased to 0.2 kPa in the middle stage in the nighttime, which was not an adequate condition for the growth of cut flowers. The VPD in Farms B and C in the nighttime often decreased to 0.2 kPa in the middle and late stages. The VPD in Farm D in the daytime and nighttime, however, was relatively higher during the overall period of growth, except the early stage, than the VPD in other farms which kept a high humidity level.

The daily integrated solar radiation was 169~4884 $\text{W}\cdot\text{m}^{-2}\cdot\text{day}^{-1}$ in Farm A, 53~4344 $\text{W}\cdot\text{m}^{-2}\cdot\text{day}^{-1}$ in Farm B,

Figure 2. Comparison of average daytime (A) and nighttime (B) relative humidity of four farms during autumn and winter culture in cut chrysanthemum 'Jinba'.

Figure 3. Comparison of average daytime (A) and nighttime (B) vapor pressure deficit of four farms during autumn and winter culture in cut chrysanthemum 'Jinba'.

406~6172 $\text{W} \cdot \text{m}^{-2} \cdot \text{day}^{-1}$ in Farm C, and 280~6078 $\text{W} \cdot \text{m}^{-2} \cdot \text{day}^{-1}$ in Farm D (Fig. 4), and the level after mid November in Farms B and C was relatively lower than that in Farms A and D.

Analysis of the cultivation methods of chrysanthemum farms

The status of cuttings for producing rooted cuttings in the 4 farms was examined (Table 1), and the length of cuttings in Farm A was longest (8.5 cm), and that in Farm D was shortest (6.5 cm). The number of leaves on a cutting was 4.5 in Farm A, and that in Farms B, C and D was similar (3.6~3.7). The stem diameter of a cutting was similar (2.7~2.9 mm) in the 4 farms. For plug cutting, 5 cm-long chrysanthemum cuttings are usually used for plug cutting, but all the 4 farms in this study used a direct cutting method, and thus the length of cuttings was longer than that of cuttings used for plug cutting.

Cuttings were planted in the 4 farms in mid October and treated with light in the nighttime, and, after planting, the period of vegetative growth (days before lights out), and days to flowering after lights out were measured. The period of vegetative growth in Farms A and C was 61~67 days, and that in Farm B was shortest (47 days). Days to flowering after lights out in Farm A was shortest (45 days), and that in Farms B and C was 61~64 days. There is a difference between the period of vegetative growth and that of reproductive growth of standard chrysanthemums depending on their varieties and cropping types, and Hwang et al. (2010) reported that the vegetative growth period of Jinba after direct cutting and before lights out was 60 days, and that after lights out and before flowering was 55 days, 115 days in total. In addition, in the

Figure 4. Comparison of integrated solar radiation of four farms during autumn and winter culture in cut chrysanthemum 'Jinba'.

Table 1. Cutting condition and growth period of cut chrysanthemum 'Jinba' in four farms during autumn and winter culture.

Farm	Cutting condition			Growth period		
	Cutting length (cm)	No. of leaves	Cutting diameter (mm)	Period of vegetative growth (Days)	Days to flowering after light out	Days to flowering after planting
A	8.5 a ²	4.5 a	2.8 a	67	45	112
B	7.3 bc	3.7 b	2.8 a	47	61	108
C	7.5 b	3.6 b	2.9 a	61	64	125
D	6.5 c	3.7 b	2.7 a	50	52	102

²Mean separation within column by Duncan's multiple range test at 5% level.

study of Roh and Yoo (2010), the vegetative growth period of Jinba after plug cutting and before lights out was 52 days, and that after lights out and before flowering was 53 days, 105 days in total. Considering the results of these earlier studies, the period of vegetative growth after planting in Farm B was shortest, and the period of vegetative growth in Farm A was relatively shorter than others.

Irrigation methods used in the 4 farms were examined. Farm A watered flowers once a day with $6.0 \text{ L} \cdot \text{m}^{-2} \cdot \text{day}^{-1}$ water, and, during the period of cultivation, a total of $702 \text{ L} \cdot \text{m}^{-2}$ water, which was more than other farms (Table 2). Farms B and D watered flowers once a day with 4.5 and $2.0 \text{ L} \cdot \text{m}^{-2} \cdot \text{day}^{-1}$ water respectively, and, during the period of cultivation, a total of 486 and $204 \text{ L} \cdot \text{m}^{-2}$ respectively. Farm C watered flowers once three days with $1.1 \text{ L} \cdot \text{m}^{-2} \cdot \text{day}^{-1}$ water, a total of $49.5 \text{ L} \cdot \text{m}^{-2}$, which was less than other farms.

Soil in the 4 farms was sampled to test chemical properties, and the results are as shown in Table 2. The pH level of soil in Farms A and D was 7.6 respectively, and the level in Farms B and C was relatively low ($6.0\sim 6.2$). The level of EC in Farms B and C was high ($3.3\sim 4.0 \text{ ds} \cdot \text{m}^{-1}$) and that in Farm D was lowest ($0.8 \text{ ds} \cdot \text{m}^{-1}$).

The quality of cut flowers of chrysanthemum farms

The growth and development status of cut chrysanthemum Jinba produced by the 4 farms was examined, and it was found that the length of cut flowers in Farm A was longest (96.9 cm), and that of cut flowers in Farm B was shortest (63.3 cm) (Table 3). The stem diameter of cut flowers in Farm A was longest (6.9 mm), and that of cut flowers in Farm B was shortest (5.0 mm). The flower width of cut flowers in Farm A was largest (24.0 mm), and that of cut flowers in Farms B, C and D was similar ($21.1\sim 22.7 \text{ mm}$). The weight of cut flowers in Farm A was also largest (83.5 g), and that of cut

Table 2. Irrigation method and soil chemical properties of four farms during autumn and winter culture in cut chrysanthemum 'Jinba'.

Farm	Irrigation method			Soil chemical properties	
	Irrigation amount ($\text{L} \cdot \text{m}^{-2} \cdot \text{day}^{-1}$)	Irrigation intervals (Days)	Total irrigation amount ($\text{L} \cdot \text{m}^{-2}$)	pH	EC ($\text{ds} \cdot \text{m}^{-1}$)
A	6.0	1	702.0	6.7 a ^z	2.0 b
B	4.5	1	486.0	6.2 b	4.0 a
C	1.1	3	49.5	6.0 b	3.3 ab
D	2.0	1	204.0	6.5 a	0.8 c

^zMean separation within column by Duncan's multiple range test at 5% level.

Table 3. Growth characteristics and vase life of cut chrysanthemum 'Jinba' produced in four farms in autumn and winter culture.

Farm	Stem length (cm)	Stem diameter (mm)	Flower diameter (mm)	Fresh weight (g)	Number of leaves	Chlorophyll (SPAD)	Vase life (Days)
A	96.9 a ^z	6.9 a	24.0 a	83.5 a	45.1 a	69.1 a	15.1 a
B	63.3 c	5.0 c	22.7 b	39.6 c	36.4 b	48.1 c	15.5 a
C	84.8 b	5.7 b	21.1 b	57.2 b	43.2 a	58.9 b	15.8 a
D	88.3 b	5.2 bc	21.6 b	62.7 b	42.7 a	47.1 c	13.7 b

^zMean separation within column by Duncan's multiple range test at 5% level.

flowers in Farms C and D was between 57.2 g and 62.7 g. The weight of cut flowers in Farm B was smallest (39.6 g). The number of leaves on cut flowers in Farms A, C and D was relatively high (42.7~45.1), and that on cut flowers in Farm B was lowest (36.4). The content of chlorophyll in the leaves of cut flowers in Farm A was highest (69.1), and that in the leaves of cut flowers in Farms B and D was relatively small (47.1~48.1). There was no difference in the vase life of cut flowers in Farms A, B and C (15.4~15.7 days), and the vase life of cut flowers in Farm D was shortest (13.7 days).

Correlation between cultivation conditions and the quality of cut flowers

Correlation between cultivation conditions and the quality of cut flowers was analyzed and the results are as shown in Table 4. The average temperature in the daytime showed a strong negative correlation with the vase life of cut flowers, and the average temperature in the nighttime had a weak negative correlation with the growth and vase life of cut flowers. The average temperature in the daytime in Farm A was higher than other farms during the early vegetative growth period and the overall reproductive growth period, which is attributable to the reduced vase life of cut flowers. In addition, the average temperature in the nighttime in Farms A and B was higher than the rest two farms, which also seems to result in the poor growth of cut flowers in the farms. In an earlier study, it was found that the growth of cut flowers, such as the length and weight of cut chrysanthemum Baekma and Jinba, and the number of leaves, was suppressed when they were grown at a higher temperature (18°C) than those grown at 14°C in the nighttime (Choi et al., 2009). In addition, Lee and Cho (2011) reported that the growth of cut flowers was poor when the temperature in the nighttime was increased from 13°C to 21°C. Among cut chrysanthemum, the buds of autumn varieties grew abnormally or the growth of those autumn varieties was delayed due to high temperature in summer (Cockshull and Kofranek, 1994; Chin et al., 1999), but Jinba flowers tested in this study are usually grown between autumn and winter, and thus their growth was not suppressed by high temperature. The results of this study indicated that temperature in the daytime affected the vase life of cut chrysanthemum Jinba, and that temperature in the nighttime affected the growth of cut chrysanthemum Jinba. Different results seem to be obtained depending on cropping types.

The average relative humidity in the daytime and nighttime did not show any statistically significant difference in terms of the growth of cut flowers, but had a strong positive correlation with the vase life of cut flowers. In an earlier study, it

Table 4. Correlation analysis of cultivation environment factors and quality of cut flower of cut chrysanthemum 'Jinba' produced in four farms in autumn and winter culture.

	Cultivation environment factors ^z						
	DT	NT	DRH	NRH	DVPD	NVPD	SR
Stem length	0.33	-0.22	-0.48	-0.24	0.43	0.18	0.55
Stem diameter	-0.03	-0.71	0.15	0.41	-0.15	-0.46	-0.02
Flower diameter	0.22	-0.39	0.32	0.49	-0.19	-0.46	-0.78
Fresh weight	0.59	-0.14	-0.38	-0.12	0.43	0.10	0.02
Number of leaves	0.18	-0.31	-0.41	-0.17	0.33	0.10	0.62
Chlorophyll content	-0.27	-0.85*	0.32	0.56	-0.35	-0.61	-0.01
Vase life	-0.92** ^y	-0.48	0.85*	0.70	-0.90**	-0.69	-0.29

^zDT: average day temperature, NT: average night temperature, DRH: average day relative humidity, NRH: average night relative humidity, DVPD: average day vapor pressure deficit, NVPD: average night vapor pressure deficit, SR: solar radiation

^y*, ** mean significant at $p=0.05$ or 0.01 , respectively, ANOVA.

was found that the relative humidity in facilities for cut chrysanthemum affects the occurrence of white rust and the growth of cut flowers, and that cut flowers grow well at 70~80%, controlled using a dehumidifier, than at a higher relative humidity (Yoo et al., 2016). Unless the relative humidity in facilities is kept at 90% or more continuously by opening and closing side windows and naturally ventilating facilities, the growth of cut flowers does not seem to be affected significantly. Humidity in facilities affects opening and closing stomata, and thus the vase life of cut flowers, and it was reported that the stomata of roses cannot be properly controlled at a relative humidity of 90% or more, reducing the vase life of cut flowers (Mortensen and Gislerod, 2000; Torre and Field, 2001). In this study, the vase life of cut flowers in Farm D where the relative humidity was maintained at 60% or less for a relatively long time was short, and these results indicate that the vase life of cut chrysanthemum Jinba flowers is significantly affected by humidity conditions out of the proper humidity range (70~80%).

It was reported that the VPD in facilities for cut chrysanthemum affects the growth of cut flowers (Mortensen, 2000; Yoo et al., 2016), but in this study the VPD in the daytime and nighttime did not show any statistically significant difference in the growth of cut flowers. Hahn et al. (1998) reported that cut chrysanthemum 'Bonghwang' flowers grew poorly in dry conditions at a VPD of 1.7 kPa, compared to those that grew at 0.8 kPa, and their transpiration and photosynthesis rates were low. In this study, the vase life of cut chrysanthemum Jinba was shortest in Farm D where the VPD was over 1.0 kPa, which indicates that the VPD has a strong correlation with the vase life of cut flowers, and shows statistically significant results. Therefore, it is very important to keep proper temperature, humidity and VPD levels in the daytime and nighttime to extend the vase life of cut chrysanthemum Jinba.

Solar radiation also affects the growth of chrysanthemums, and the higher the intensity of light, the more chlorophyll in leaves, and the higher the photosynthesis rate (Lee et al., 2001; Lee et al., 2002)). Jinba flowers tested in this study, however, are grown from autumn to winter when the solar radiation is relatively lower than spring and summer, and thus cut chrysanthemum Jinba flowers do not show a statistically significant correlation between the solar radiation and the quality of cut chrysanthemum Jinba flowers, but show a weak negative correlation between the solar radiation and the width of cut flowers.

Correlation between cultivation methods and the quality of cut flowers

The growth of cut chrysanthemum is affected by the conditions of cuttings, which affects not only rooting but also the growth of cut chrysanthemum Jinba and Baekseon after cutting (Yoo and Roh, 2009; Roh and Yoo, 2010). When the length of Jinba cuttings was 9 cm; the number of leaves, 4~6; and diameter, 3.2 mm, the length and diameter of cut flowers were longer than other cut flowers. When Baekseon cuttings were cut to be 7~11 cm long (the number of leaves: 4~6, diameter: 4.5 mm), the growth of cut flowers was good. In this study, the length of cuttings had mostly a positive correlation with the growth of cut flowers, and in particular, the stem diameter of cut flowers had a strong positive correlation with the content of chlorophyll, which showed a statistically significant difference (Table 5). The number of leaves had a strong positive correlation with the stem diameter of cut flowers, flower width and fresh weight, but had a weak correlation with the vase life of cut flowers. The diameter of cuttings had a weak positive correlation with the vase life of cut flowers.

Since cut chrysanthemum Jinba, as an autumn-winter variety, go through a certain vegetative growth period, and enter a reproductive growth phase after receiving short-day treatment, the vegetative growth period affects the growth of cut flowers. In the case of 'Hwangeza,' an autumn chrysanthemum variety for flower beds, the length of cut flowers and fresh weight were better when they received short-day treatment after going through 65 days of vegetative growth than after going through 25~55 days of vegetative growth (Chin et al., 1999). In addition, 'Geumbit,' an autumn pot-mum variety,

Table 5. Correlation analysis of cropping system factors and quality of cut flower of cut chrysanthemum 'Jinba' produced in four farms in autumn and winter culture.

	Cropping system factors ^z									
	CL	LNC	CD	PVG	PRG	IA	II	TIA	SPH	SEC
Stem length	0.36	0.60	0.09	0.37	-0.86*	0.03	0.07	0.72	0.66	-0.73
Stem diameter	0.88* ^y	0.90**	0.36	0.71	-0.70	0.53	0.00	0.82*	0.82*	-0.23
Flower diameter	0.73	0.89*	-0.17	0.18	-0.51	0.99**	-0.65	0.12	0.84*	-0.01
Fresh weight	0.48	0.88*	-0.27	0.14	-0.98**	0.54	-0.47	0.41	0.96*	-0.71
Number of leaves	0.37	0.52	0.24	0.49	-0.76	0.47	0.24	0.81*	0.56	-0.64
Chlorophyll content	0.92**	0.79	0.57	0.86*	-0.51	0.45	0.20	0.90**	0.67	-0.03
Vase life	0.16	-0.42	0.68	0.41	0.58	0.13	0.56	0.03	0.46	0.47

^zCL: cutting length, LNC: leaf number of cutting, CD: cutting diameter, PVG: period of vegetative growth, PRG: period of reproductive growth, IA: irrigation amount, II: irrigation interval, TIA: total irrigation amount, SPH: soil ph, SEC: soil EC

^y*, ** mean significant at $p=0.05$ or $.01$, respectively, ANOVA.

grew better when they received short-day treatment after 21 days after planting than after 7~14 days (Kim et al., 1998). In this study, cut chrysanthemum Jinba in Farms B and D where the vegetative growth period was short (47~50 days) also grew relatively poorly, which indicates that the vegetative growth period had a mostly positive correlation with the growth of cut flowers, and a strong positive correlation with the content of chlorophyll. The vegetative growth period had a mostly negative correlation with the growth of cut flowers, and in particular, a strong negative correlation with fresh weight. However, it had a low correlation with the vase life of cut flowers. Therefore, it is necessary to secure a proper vegetative growth period in order to improve the growth and the vase life of autumn-winter varieties like Jinba flowers.

The amount of irrigation also affects the growth of cut chrysanthemum, and Yoo and Roh (2012) reported that when the moisture content in soil was maintained at -40 kPa, the growth of cut flowers, such as their length and weight, was poor due to the small amount of irrigation. In this study, both the daily and total irrigation amounts showed a similar correlation with the growth and the vase life of cut flowers. They had a mostly positive correlation with the growth of cut flowers, and particularly a strong positive correlation with flower width, stem diameter, the number of leaves, and chlorophyll content. Irrigation interval had a weak negative correlation with flower width and fresh weight. The longer the interval, the smaller the flower width and the fresh weight of cut flowers. Irrigation methods had a mostly low correlation with the vase life of cut flowers.

The pH and EC of soil affects the growth of cut flowers, and it is recommended to keep the pH level and the EC of the rooting zone at 6.0~6.5, and 2.5 $\text{ds} \cdot \text{m}^{-1}$ respectively in order to produce high-quality chrysanthemum flowers (Park, 1997). In this study, the pH of soil had a positive correlation with the growth of cut flowers. In particular, it had a strong positive correlation with stem diameter, flower width and fresh weight, but a low correlation with the vase life of cut flowers. On the contrary, the EC of soil, unlike the pH level, had a weak negative correlation with the length of cut flowers and fresh weight, and a weak correlation with the vase life of cut flowers.

Conclusions

Cut chrysanthemum is divided depending on their flowering types into standard and spray chrysanthemums. The total domestic production of cut chrysanthemum in Korea in 2015 was 174 million flowers, and standard chrysanthemums

accounted for 86.6% (151 million flowers). Among standard chrysanthemums, Jinba flowers are harvested from autumn to the next spring, and consumed domestically and also exported to Japan. To produce high-quality cut chrysanthemum flowers, cultivation conditions such as the intensity of light, day length, temperature, humidity, and the VPD, and cultivation methods such as the status of cuttings, nutrients and water supply, soil conditions, and disease and insect control should be managed in a comprehensive and proper manner. Earlier studies, however, researched the quality of cut flowers focusing on a few conditions only, and thus it was difficult to understand the precise effects of a combination of multiple factors on the quality of cut flowers. In this regard, this study examined environmental conditions, including the intensity of light, temperature, humidity and the VPD, cuttings, vegetative and reproductive growth periods, irrigation methods, and soil conditions. In individual chrysanthemum farms, analyzed their correlation with the quality of cut flowers, and thus identify factors that affect the quality of cut flowers.

Correlation between cultivation conditions and the quality of cut flowers was analyzed, and the results showed that the average temperature in the nighttime has the biggest impact on the growth of cut flowers, and a negative correlation. In other words, the higher the temperature in the nighttime, the poorer the growth of cut flowers. The vase life of cut flowers had a negative correlation with the average temperature in the daytime and nighttime and the VPD, which indicates that a high temperature in the daytime and nighttime or too dry conditions, that is, a high VPD level, have a negative impact on the vase life of cut flowers. In addition, the vase life of cut flowers had a positive correlation with the average humidity in the daytime and nighttime, and it will be better to maintain a high humidity level in facilities (80~90%), if diseases and insects can be controlled well.

The results of the analysis of correlation between cultivation methods and the quality of cut flowers indicated that the growth of cut flowers had a strong positive correlation with the pH of soil and the number of leaves on cuttings, but a weak positive correlation with the length of cuttings, the vegetative growth period and the amount of irrigation. That is, long cuttings with many leaves on them need to be planted to promote the growth of cut flowers, and a large amount of irrigation and a long vegetative growth period need to be secured. It will be also necessary to maintain the pH level of soil high within a proper growth range. On the contrary, it was found that the EC of soil and the reproductive growth period have a negative correlation with the growth of cut flowers, which indicates that an excessively high EC level or an excessively long reproductive growth period have a negative impact on the growth of cut flowers.

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