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Effect of Short Day and Low Temperature at the Nursery Stage on the Inflorescence and Yield of Six Different Strawberry (*Fragaria ananassa* Dutch.) Cultivars in a Soilless Culture System

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Abstract: In Korea, the majority of strawberry cultivation follows a forcing culture, where planting occurs in mid-September after the flower differentiation, and harvesting begins at the end of November. October and November constitute off-season, resulting in higher prices. The accelerated forcing culture involves artificially promoting flower differentiation to expedite strawberry harvest. This study aimed to identify the most suitable schedule for strawberry cultivation using the short-day and low-temperature treatments through greenhouse environmental control during the nursery stage. The selection of the most suitable cultivars for accelerated forcing culture among Korean breeding cultivars ('Sulhyang', 'Kuemsil', 'Kingsberry', 'Vitaberry', 'Jukhyang', and 'Altaking') was also part of the objectives. The nursery treatments were initiated on 4 July, 14 July, and 25 July. After approximately 5 weeks of treatment, transplanting was carried out. The control group was transplanted on 15 September. When night-chilling nursery treatment was applied on 4 July, followed by transplanting on 11 August, all six cultivars exhibited flowering earlier compared to the control group, leading to increased early yield. Particularly, the 'Sulhyang' cultivar showed the highest marketable yield at 68.6 g per plant in October. This research contributes to identifying the nursery cultivation schedule for off-season strawberry production and selecting suitable cultivars, and is expected to contribute to increased farm income.

Keywords: flower differentiation; forcing culture; marketable fruit; off season

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1. Introduction

Strawberries in Korea are predominantly cultivated through forcing culture, a method of transplanting in mid-September after the differentiation of the first flower cluster and greenhouse film covering and insulation in mid- to late-September before entering dormancy in October [1]. Most Korean strawberries are harvested starting late November, resulting in a high unit price of around KRW 33,136 (USD 25.2) per kg in October and KRW 25,041 (USD 19.0) per kg in November, gradually decreasing to KRW 17,181 (USD 13.1) per kg in December when the full-scale harvest of accelerated forcing culture strawberries begins. The period from October to November experiences minimal strawberry production. Following a peak in prices, the unit price drops to KRW 8823–9032 (USD 6.7–6.9) per kg in March when a large quantity of strawberries with low marketability is supplied [2].

To enhance income, some farmers are adopting an accelerated forcing culture method, aiming to advance the strawberry harvest. This method involves artificially inducing floral differentiation. Various studies have been conducted to promote floral differentiation, including the widely used method of chilling nursery plants [3]. Unlike everbearing strawberries that can be harvested under long-day and high-temperature conditions [4], June-bearing strawberries induce floral differentiation in response to low-temperature and short-day conditions [5]. Recent efforts include attempting to induce floral differentiation artificially by manipulating the temperature and daylength before transplanting, known as the short-day and low-temperature treatment at the nursery stage [6]. Previous studies have utilized separate chilling facilities to expose nursery plants to natural light during the day and induce floral differentiation under artificially controlled low-temperature conditions at night [7–11]. However, such methods incur high facility costs and labor-intensive procedures, and often lead to dry conditions and increased susceptibility to diseases such as powdery mildew and botrytis [12]. Research on the most suitable cultivation schedule for chilling nursery treatment and transplanting in a greenhouse environment, rather than a cold storage method, is lacking. Additionally, there is a need to identify the most suitable strawberry cultivars for accelerated forcing culture among those developed in Korea.

This study aimed to determine the most economically viable cultivation schedule using short-day and low-temperature treatment in the nursery stage to induce floral differentiation in accelerated forcing culture and select the most suitable cultivars for accelerated forcing culture among six cultivars developed in Korea.

2. Materials and Methods

2.1. Plant Materials and Cultivation Management

The experiment was conducted in two greenhouses located at the National Institute of Horticultural and Herbal Science in Wanju-gun, Jeollabuk-do. Pots (multi-cup type D, Hwasung Industrial Co., Ltd., Jinju, Republic of Korea) for transplanting the mother plants were placed in a double-span plastic greenhouse and filled with horticultural strawberry substrates using a mixture of coir, peat, and pearlite (Hanareum type A, Sinsung Mineral, Seongnam, Republic of Korea). On 8 March 2022, the mother plants of six strawberry cultivars (*Fragaria* × *ananassa* Duch. 'Sulhyang', 'Kuemsil', 'Kingsberry', 'Vitaberry', 'Jukhyang', and 'Altaking') were transplanted, and runners were induced in 24-cell pots (510 mm × 340 mm × 100 mm, 168 mL/cell, Hwasung Industrial Co., Ltd., Jinju, Republic of Korea). Depending on the treatment date, the plantlets were moved to a single-span plastic greenhouse (width 28 m, height 14 m, length 32 m) for the short-day and low-temperature treatments, followed by transplanting.

2.2. Greenhouse Conditions

The double-span plastic greenhouse for inducing runners had a cultivation bed for inducing plantlets, nutrient solution management through an automatic nutrient solution supply system, and greenhouse environment control using a shading screen; however, it did not have cooling or blackout facilities. For the short-day and low-temperature treatment of plantlets, the plantlets were moved to a single-span plastic greenhouse equipped with cooling and blackout facilities. Temperature and relative humidity within the single-span greenhouse were measured every 5 s using an environmental data logger (MAGMAPLUS-1000, Green Control System, Damyang, Republic of Korea). During the cultivation period, the average monthly external temperatures were 23.7 °C in August, 19.5 °C in September, 11.7 °C in October, and 7.9 °C in November, whereas the average monthly internal temperatures were 19.0 °C in August, 18.9 °C in September, 12.1 °C in October, and 15.7 °C in November. The short-day and low-temperature treatment periods in the single-span greenhouse were 4 July–11 August, 14 July–18 August, and 25 July–25 August. The average daytime temperatures from 9 am to 5 pm were 28.7 °C, 28.3 °C, and 28.1 °C, and the average nighttime temperatures from 6 pm to 8 am were 21.0 °C, 20.6 °C, and 20.3 °C, respectively. From 4 July to 25 August, the temperature inside the greenhouse was 28.5 °C from 9 am to 5 pm, 23.4 °C from 6 to 9 pm, 20.3 °C from 10 pm to 12 am, 19.5 °C from 1 to 4 am, and 19.5 °C from 5 to 8 am. The monthly cumulative solar radiation was 1285 W/m^2 in August, 1407 W/m^2 in September, 1371 W/m^2 in October, and 1074 W/m^2 in November. No supplemental light was used in this experiment. Only natural sunlight was utilized during the nursery stage and after transplanting.

2.3. Soilless Culture System

Raised beds (spacing 130 cm) with styrofoam boxes (width 37 cm, length 200 cm) were filled with the strawberry substrates using a mixture of coir, peat, and pearlite (Cham Grow No. 2, Cham Grow Inc., Hongseong, Republic of Korea). On 9 August 2022, a drip irrigation tape was installed, and the substrates were irrigated with groundwater (electrical conductivity (EC) 0.34 dS·m^{-1}, pH 7.26). Depending on the treatment date, the strawberry plantlets were transplanted at 16 cm intervals in the styrofoam boxes. In total, 34 beds were arranged in the greenhouse; each bed was 1.1 m long and contained 10 styrofoam boxes.

2.4. Nutrient Solution Management and Irrigation

In the nursery stage, a standard nutrient solution was prepared following the Gyeongsangnam-do Agricultural Research and Extension Services for the nursery stage [13] (macronutrients: NO_3-N 12.0 mg·L^{-1}, NH_4-N 0.6 mg·L^{-1}, PO_4-P 4.4 mg·L^{-1}, K 6.0 mg·L^{-1}, Ca 8.0 mg·L^{-1}, Mg 4.0 mg·L^{-1}, SO_4-S 4.0 mg·L^{-1}; micronutrients: Fe 3.00 mg·L^{-1}, B 0.50 mg·L^{-1}, Mn 0.50 mg·L^{-1}, Zn 0.20 mg·L^{-1}, Cu 0.04 mg·L^{-1}, Mo 0.04 mg·L^{-1}) and supplied to the substrates. Irrigation was carried out three times a day using a fertilization system (SH-1004, SHINHAN A-TEC, Masan, Republic of Korea). First irrigation was carried out at 9:00, and the last irrigation was at 15:00. After transplanting, irrigation was carried out five to six times a day using a nutrient solution-supplying system (MAGMA-1000 V2.0, Green Control System, Damyang, Republic of Korea) with the daily nutrient supply varying from 300 to 450 mL depending on the growth stage [1]. The standard nutrient solution was prepared following the Gyeongsangnam-do Agricultural Research and Extension Services after transplanting [14] (macronutrients: NO_3-N 13.0 mg·L^{-1}, NH_4-N 0.8 mg·L^{-1}, PO_4-P 4.4 mg·L^{-1}, K 6.3 mg·L^{-1}, Ca 8.0 mg·L^{-1}, Mg 4.0 mg·L^{-1}, SO_4-S 4.0 mg·L^{-1}; micronutrients: Fe 3.00 mg·L^{-1}, B 0.50 mg·L^{-1}, Mn 0.50 mg·L^{-1}, Zn 0.20 mg·L^{-1}, Cu 0.04 mg·L^{-1}, Mo 0.04 mg·L^{-1}) and supplied to the substrates. The first irrigation was supplied at 9:00, and the last irrigation was supplied at 17:20, for a total of six times at intervals of 1 h and 40 min.

2.5. pH and EC Management

The nutrient solution had an EC of 0.71.2 dS·m^{-1} and a pH of 6.0. EC and pH were automatically measured every 5 s using the nutrient solution-supplying system. The EC and pH were adjusted by comprehensively judging the drained nutrient solution, the color of strawberry leaves, and tip burn symptoms. The lowest EC of the supplied solution did not exceed 0.7 dS·m^{-1}, and the highest EC of the supplied solution did not exceed 1.2 dS·m^{-1}.

2.6. Experimental Design and Treatments

The short-day and low-temperature treatment at the nursery stage began by moving plantlets from the nursery greenhouse to the environmental treatment greenhouse on three treatment dates: 4 July, 14 July, and 25 July. They were transplanted in the same greenhouse about 5 weeks after treatment. The control group was transplanted on 15 September without environmental treatment. The temperature and photoperiod treatment involved using blackout curtains and ventilation ducts. The photoperiod treatment consisted of 8 h of daylight and 16 h of darkness: at 5 PM, the blackout curtains were lowered, and cooling was initiated; at 9 AM, the curtains were raised. The daytime temperatures did not exceed 35 °C and nighttime temperatures did not drop below 18 °C. The greenhouse door was covered with a black polyethylene film, and shade (OBSCURA, AB Ludvig Svensson, Kinna, Sweden), side, and front curtains (Yuk-il Agro Spun Curtain Co., Seongju, Republic of Korea) were used to create a blackout environment. Transplanting dates varied according to the short-day and low-temperature treatment period. The plantlets in the 4 July treatment were transplanted on 11 August, with the short-day and low-temperature treatment period lasting from 4 July to 11 August; those in the 14 July treatment were transplanted on 18 August, with the short-day and low-temperature treatment period lasting from 14 July to 18 August; and those in the 25 July treatment were transplanted on 25 August, with the short-day and low-temperature treatment period lasting from 25 July to 25 August. The experiment started on 8 March 2022 with the transplantation of the mother plant and concluded on 25 July 2023 with the end of the harvest (Table 1 and Figure 1).

Table 1. Experimental set-up with the six June-bearing strawberry cultivars (*Fragaria* × *ananassa* Duch. 'Sulhyang', 'Kuemsil', 'Kingsberry', 'Vitaberry', 'Jukhyang', and 'Altaking') in the nursery period affected by the short-day and low-temperature treatment and the conditions of the greenhouse after transplanting.

	Nursery Stage Treatment	After Transplanting
Temperature (day/night)	28/18 °C	28/8 °C
Day length (day/night)	8/16 h	8/16 h
Duration	Starting on 4/7, 14/7, and 25/7 in 5 weeks (around 40 day-old plantlet age)	Transplanting on 11/8, 18/8, 25/8, and 15/9 (control)
Substrate	Mixture of coir, peat, and pearlite (Hanareum type A, Sinsung Mineral, Seongnam, Republic of Korea)	Mixture of coir, peat, and pearlite (Cham Grow No. 2, Cham Grow Inc., Hongseong, Republic of Korea)
Fertilization	Standard nutrient solution of Gyeongsangnam-do Agricultural Research and Extension Services for the nursery stage (macronutrients: NO_3-N 12.0 mg·L^{-1}, NH_4-N 0.6 mg·L^{-1}, PO_4-P 4.4 mg·L^{-1}, K 6.0 mg·L^{-1}, Ca 8.0 mg·L^{-1}, Mg 4.0 mg·L^{-1}, SO4-S 4.0 mg·L^{-1}; micronutrients: Fe 3.00 mg·L^{-1}, B 0.50 mg·L^{-1}, Mn 0.50 mg·L^{-1}, Zn 0.20 mg·L^{-1}, Cu 0.04 mg·L^{-1}, Mo 0.04 mg·L^{-1})	Standard nutrient solution of Gyeongsangnam-do Agricultural Research and Extension Services after transplanting (macronutrients: NO_3-N 13.0 mg·L^{-1}, NH_4-N 0.8 mg·L^{-1}, PO_4-P 4.4 mg·L^{-1}, K 6.3 mg·L^{-1}, Ca 8.0 mg·L^{-1}, Mg 4.0 mg·L^{-1}, SO_4-S 4.0 mg·L^{-1}; micronutrients: Fe 3.00 mg·L^{-1}, B 0.50 mg·L^{-1}, Mn 0.50 mg·L^{-1}, Zn 0.20 mg·L^{-1}, Cu 0.04 mg·L^{-1}, Mo 0.04 mg·L^{-1})
Irrigation system	Drip irrigation with timer control, three times a day, open system	Drip irrigation with timer control, six times a day, open system
Size of pots	24-cell pots, 510 mm × 340 mm × 100 mm, 168 mL/cell	Styrofoam boxes (width 37 cm, length 200 cm)

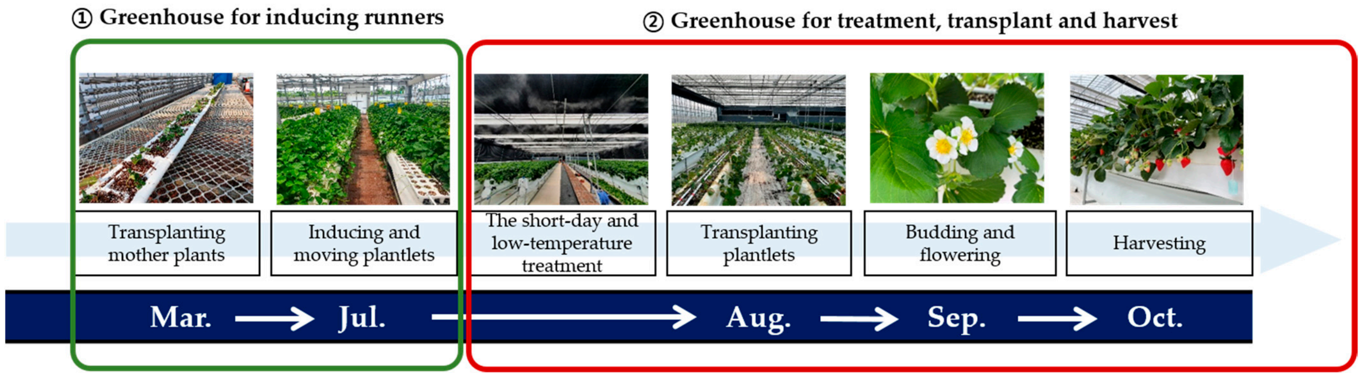

Figure 1. Schematic diagram of the experiment with the six June-bearing strawberry cultivars (*Fragaria* × *ananassa* Duch. 'Sulhyang', 'Kuemsil', 'Kingsberry', 'Vitaberry', 'Jukhyang', and 'Altaking') in the nursery period affected by the short-day and low-temperature treatment.

2.7. Growth Characteristics and Mineral Contents in the Nursery Stage

The growth characteristics of the plantlets were measured according to the standards in the Rural Development Administration's Vegetable Research Data Standard Manual [15]. Plantlet growth characteristics were measured in two stages: the first measurement was conducted on the 22nd day after the short-day and low-temperature treatment (mid-stage), and the second measurement was carried out during the transplanting stage, 35 d after the treatment (late-stage). The investigation was conducted with five plants and three replicates. The parameters measured included leaf number, leaf area, leaf length, leaf width, crown diameter, primary root number, aerial and root parts' fresh weight, and dry weight. Crown diameter was measured using digital callipers (CD-20CPX, Mitutoyo Corp., Kawasaki, Japan). The fresh weight of each plantlet was measured using an electronic balance (CAS, Seoul, Republic of Korea), and the dry weight of each plantlet was determined by drying the plantlets in a drying oven (KNS-520S, Kyeongnong, Yeoncheon, Republic of Korea) at 75 °C for 72 h and weighing the samples. The top/root (T/R) ratio was calculated using the fresh weight of the aerial part and the root part. To perform a rapid analysis of inorganic elements in plant tissues, leaf juice was squeezed and analyzed for soluble solid contents (SSC), nitrate nitrogen (NO_3-N), and calcium contents using an ion meter (LAQUA twin, Ion Meter; Horiba Ltd., Kyoto, Japan).

2.8. Inflorescence Characteristics

Flowering characteristics after transplanting were observed based on the standards described in the Rural Development Administration's Vegetable Research Data Standard Manual [15]. Starting on 5 September, the budding and flowering status were assessed at 5–7 d intervals. Onset of budding was defined as the time when the flower bud had grown to approximately 1 cm, accounting for about 40% of the assessed plants, while full bloom was defined as the time when the first flower had fully opened, accounting for about 40% of the assessed plants. The investigation was conducted with 20 plants and three replicates.

2.9. Yield and Fruit Quality Characteristics

The yield and quality characteristics of the strawberries were assessed based on the standards described in the Rural Development Administration's Vegetable Research Data Standard Manual [15]. The fruits were harvested at one-week intervals from 30 September 2022 to 25 July 2023. The investigation was conducted with 20 plants and three replicates. All fruits were measured in this investigation. Fruits weighing 12 g or more were categorized as marketable fruits and classified into seven categories: 12–17 g, 17–22 g, 22–27 g, 27–32 g, 32–37 g, 37–42 g, and $\geq$42 g. Fruits weighing less than 12 g and those with distorted shapes or that were malformed were categorized as unmarketable fruits and excluded from the marketable fruit rate calculation. The marketable fruit rate was calculated as the proportion of fruits excluding undersized or malformed fruits from the total yield. Yield per unit area (kg/m^2) was determined based on a bed spacing of 130 cm, double-row planting, and a plant interval of 16 cm, assuming that there were 9.62 plants per square meter. It was calculated by multiplying the yield of marketable fruits with the number of plants per sq. m.

The fruit quality characteristics investigated once a month included SSC (measured as sugar content, °Brix), firmness, acidity, sugar–acid ratio, fruit weight, fruit length, and fruit width. The SSC of the leaf juice was measured in °Brix using a portable digital refractometer (PAL-1, ATAGO CO. Ltd., Tokyo, Japan), and the ratio of SSC to NO_3-N was calculated. Fruit firmness was measured in $g\cdot mm^{-2}$ and determined using a firmness tester (FHM-1, Takemura Techno Works Co., Ltd., Kyoto, Japan), and the acidity was determined using an automatic titrator (TitroLine easy, SCHOTT Instruments Gmbh, Mainz, Germany). The investigation was conducted with five fruits and three replicates.

2.10. Statistical Analysis

Statistical analysis was conducted using Sigmaplot (SigmaPlot 8.0, Systat Software, Inc., Chicago, IL, USA), Excel (Excel 2016, Microsoft, Redmond, WA, USA), and R (R 4.3.1, R Foundation). Multiple comparisons of the means were performed using Duncan's multiple range test ($p \leq 0.05$).

3. Results and Discussion

3.1. Growth Characteristics of Strawberry Plantlets

Analysis of the growth characteristics of strawberry plantlets under short-day and low-temperature conditions at different periods revealed the following results (Table 2). After approximately 20 d of observation following the 4 July treatment, the 'Kuemsil' cultivar showed the least root growth during the initial investigation. Compared to 'Jukhyang', 'Kuemsil' displayed 52.6% fewer primary roots, with only 9.3 primary roots. Even in the 14 July treatment, 'Kuemsil' had the lowest number of primary roots; compared to 'Kingsberry', it had 36.5% fewer primary roots. Among the six cultivars, 'Jukhyang' exhibited the shortest height in all three treatments (4 July, 14 July, and 25 July), with measurements of 29.4 cm, 27.8 cm, and 23.9 cm, respectively. These findings suggest that 'Jukhyang' exhibits vigorous growth without significant overgrowth during high-temperature periods. Approximately 35 d after the temperature and photoperiod treatments, late-stage nursery growth showed an increase compared to mid-stage nursery growth. On 4 July, 14 July, and 25 July, the 'Kuemsil' cultivar exhibited the lowest number of primary roots among the six cultivars, with 11.9, 8.4, and 8.5 primary roots, respectively. This indicates that 'Kuemsil' has a relatively weak root development during the high-temperature period. Since the development of the root part is weaker than that in other cultivars, it is advisable to start early transplanting of mother plants and induce early rooting in 'Kuemsil' cultivation. It is thought that obtaining sufficient plantlet age through proper environmental management before initiating the short-day and low-temperature treatment in the nursery stage will contribute to the production of high-quality plantlets. Similar to our observations of its mid-stage growth, 'Jukhyang' had the lowest height among the six cultivars on 4 July, 14 July, and 25 July, with its height being 27.4%, 21.2%, and 30.1% lower than that of 'Kuemsil', respectively. During high-temperature periods, 'Kuemsil' exhibited aerial part overgrowth and weak root development. On the other hand, 'Jukhyang' exhibited a low height and well-developed root growth, suggesting its suitability for high-temperature nursery cultivation. Regarding the aerial part growth during both the mid- and late-nursery stages, 'Sulhyang' ranked in the middle among the six cultivars. Similar to 'Jukhyang', it exhibited strong root development during the high-temperature nursery period.

Furthermore, we analyzed the mineral content of the plants after the short-day and low-temperature treatment (Figure 2). In the July 4 treatment, during the late-nursery stage after transplanting, the nitrate-nitrogen content of all cultivars decreased as follows: in 'Sulhyang' it decreased by 75%, in 'Kuemsil' by 47%, in 'Kingsberry' by 54%, in 'Vitaberry' by 51%, in 'Altaking' by 63%, and in 'Jukhyang' by 62%. This reduction was attributed to the lack of nutrient supply during the short-day and low-temperature treatment. The analysis also revealed a trend of decreasing nitrate-nitrogen content between the mid- and late-nursery stages in the 14 July and 25 July treatments. This observation confirmed that the application of nutrient solution during the short-day and low-temperature nursery period led to a reduction in the nitrate-nitrogen content. Nitrate-nitrogen plays a crucial role in floral induction. Flowering strawberry plants have a lower nitrate content than non-flowering plants [16,17]. High nitrate content prior to floral induction suppresses flowering, whereas post-induction, it promotes flowering [18,19]. The temperature and photoperiod primarily govern strawberry floral induction, but differences in nitrogen levels during the same temperature conditions significantly impact the initiation of flowering. Susceptibility to low temperature increases when the nitrogen level in the plantlets is low [12]. In the present study, the calcium content in the plants increased during the late-nursery stage, presumably because of increased calcium ion absorption into the plant each day after planting. In both the mid- and late-nursery stages, the calcium content was higher in the 25 July treatment than in the 1 July treatment. Among the six cultivars, 'Kuemsil' and 'Jukhyang' had the highest calcium contents. In the 25 July treatment, compared to that of 'Kingsberry', the calcium contents of 'Kuemsil' and 'Jukhyang' were 138% and 159% higher in the early-nursery stage and 119% and 46% higher in the late-nursery stage, respectively. The C/N ratio plays a critical role in plant flowering. A lower C/N ratio suppresses flowering, whereas a higher C/N ratio promotes it [12]. Here, we examined the SSC/NO_3-N ratio in the late-nursery stage. In the 4 July treatment, the SSC/NO_3-N ratio of all cultivars was higher than that in the 25 July treatment. Although 'Sulhyang' did not show a significant difference in the SSC/NO_3-N ratio according to the treatment date, 'Kuemsil', 'Kingsberry', 'Vitaberry', 'Jukhyang', and 'Altaking' exhibited 119%, 128%, 52%, 98%, and 57% higher SSC/NO_3-N ratio values, respectively, in the 4 July treatment than those in the 25 July treatment. This indicates that floral induction occurred faster in the 4 July treatment than in the 25 July treatment.

Table 2. Growth characteristics of six strawberry cultivars in the nursery period affected by the short-day and low-temperature treatment (three treatment start dates: 4 July, 14 July, and 25 July) during the middle stage (a, approximately 20 d after the short-day and low-temperature treatment) and late stage (b, approximately 35 d after the short-day and low-temperature treatment).

Treatment [z]	Nursery Stage	Cultivar	No. of Leaves	Plant Height (cm)	Petiole Length (cm)	Leaf Length (cm)	Leaf Width (cm)	Crown Diameter (mm)	No. of Primary Roots
4 July	Mid-stage	Sulhyang	3.3 c–f [y]	32.2 c–e	17.9 c–g	7.7 b–e	6.7 a–c	8.63 cd	17.1 a–c
		Kuemsil	3.3 c–f	34.0 a–d	19.5 b–f	7.3 c–e	5.9 b–e	8.69 cd	9.3 f
		Kingsberry	3.5 b–e	36.3 a–c	21.8 a–c	7.0 d–g	6.2 a–d	9.35 a–c	13.1 b–f
		Vitaberry	4.2 a	36.3 a–c	20.0 b–d	8.0 a–d	6.3 a–c	10.08 ab	11.8 c–f
		Jukhyang	3.3 c–f	29.4 d–g	16.2 d–g	7.8 b–d	7.0 a	10.22 a	19.6 a
		Altaking	3.9 ab	31.8 c–e	20.0 b–d	6.5 e–h	5.1 e–h	8.67 cd	11.9 c–f
	Late-stage	Sulhyang	4.5 a–e	32.7 a–d	20.8 a–c	7.0 a–c	5.6 a–d	9.58 a	16.1 b–e
		Kuemsil	4.3 a	36.9 b–e	24.2 a	7.9 a	6.0 a–c	9.57 a	11.9 c–e
		Kingsberry	3.7 a–c	34.1 e–h	23.3 ab	7.1 a–c	6.1 ab	9.64 a	15.4 b–e
		Vitaberry	4.4 b–f	31.0 b–e	19.2 b–g	7.0 a–c	5.6 a–d	9.27 a	15.2 b–e
		Jukhyang	3.9 fg	26.8 d–f	16.0 e–g	6.8 b–f	6.1 ab	9.36 a	15.1 b–e
		Altaking	5.0 a–e	33.1 a–c	22.0 a–c	5.8 d–f	6.4 ab	9.55 a	16.5 bc
18 July	Mid-stage	Sulhyang	3.5 b–e	32.9 b–e	19.6 b–e	8.1 a–d	6.8 ab	10.17 ab	16.7 a–d
		Kuemsil	3.8 a–d	39.2 a	23.3 ab	9.0 a	6.8 ab	10.28 a	11.5 d–f
		Kingsberry	2.9 f	36.3 a–c	20.5 b–d	7.6 b–e	6.9 ab	10.44 a	18.1 ab
		Vitaberry	3.3 c–f	32.3 c–e	19.6 b–e	8.4 a–c	6.7 a–c	9.23 a–d	15.2 a–e
		Jukhyang	3.1 ef	27.8 e–g	15.0 fg	7.0 d–g	6.3 a–c	8.53 cd	14.3 a–f
		Altaking	4.3 a	30.5 c–f	18.3 c–g	6.0 gh	4.6 gh	8.53 cd	15.7 a–c
	Late-stage	Sulhyang	3.7 b–f	31.6e –h	19.8 a–f	7.5 ab	6.1 ab	9.95 a	25.0 a
		Kuemsil	3.1 ab	35.4 h	21.3 a–c	7.3 ab	5.6 a–d	8.93 a	8.4d e
		Kingsberry	3.5 d–f	28.6 f–h	20.6 a–e	7.4 ab	6.7 a	9.92 a	17.7 bc
		Vitaberry	3.5 b–f	30.2 f–h	15.8 fg	6.8 b–d	5.4 a–d	9.26 a	13.9 b–e
		Jukhyang	3.3 ef	27.9 gh	18.0 c–g	6.5 b–f	6.1 ab	9.05 a	19.5 a–c
		Altaking	5.1 a–c	34.0 ab	19.2 b–g	5.6 f	4.0 d	9.54 a	20.2 ab
25 July	Mid-stage	Sulhyang	3.3 d–f	28.8 d–g	16.7 d–g	6.6 e–h	5.3 d–g	8.37 cd	14.3 a–f
		Kuemsil	3.7 a–d	38.7 ab	25.8 a	8.7 ab	6.6 a–c	9.88 ab	12.8 b–f
		Kingsberry	3.3 c–f	28.2 d–g	17.3 c–g	7.2 d–f	6.7 a–c	8.58 cd	13.9 b–f
		Vitaberry	3.4 b–f	27.1 e–g	15.1 e–g	6.1 f–h	4.9 f–h	8.27 cd	12.3 c–f
		Jukhyang	3.9 a–c	23.9 g	14.7 g	6.5 e–h	5.7 c–f	8.99 b–d	16.0 a–d
		Altaking	4.3 a	25.1 fg	15.4 e–g	5.5 h	4.3 h	8.04 d	10.0 ef
	Late-stage	Sulhyang	4.3 a–d	33.4 c–f	18.2 c–g	7.2 a–c	6.0 a–c	9.21 a	16.3 b–d
		Kuemsil	4.3 a–e	32.9 b–e	18.3 c–g	6.7 b–e	4.7 b–d	8.91 a	8.5 de
		Kingsberry	4.0 a–e	32.6 d–g	18.2 c–g	6.6 b–f	5.8 a–c	9.77 a	16.8 bc
		Vitaberry	4.2 c–g	29.0 d–f	15.2 fg	6.2 c–f	5.1 a–d	9.23 a	13.5 b–e
		Jukhyang	3.7 g	23.0 d–h	14.7 g	5.9 d–f	5.4 a–d	8.47 a	15.3 b–e
		Altaking	5.3 d–f	28.4 a	16.6 d–g	5.7 ef	4.2 cd	9.05 a	13.6 b–e

[z] The short-day and low-temperature treatment start dates: 4 July, 14 July, and 25 July; [y] mean separation within columns by Duncan's multiple range test (DMRT) at the 5% level. Different lowercase letters indicate significant differences ($p < 0.05$) between treatments.

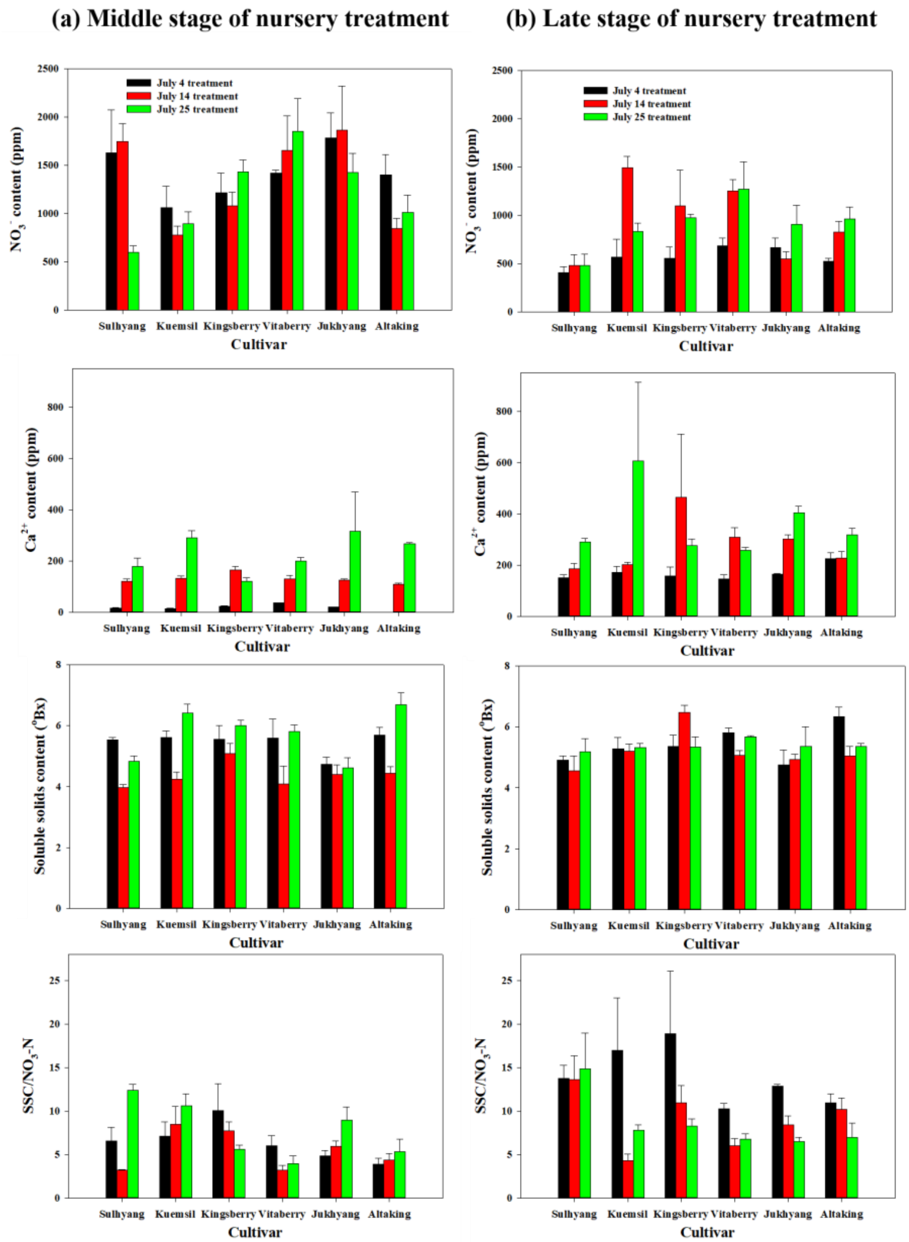

Figure 2. NO_3^- content, Ca^{2+} content, soluble solids content (SSC), and SSC/NO_3^- of six strawberry cultivars in the nursery period affected by the short-day and low-temperature treatment (three treatment start dates: 4 July, 14 July, and 25 July) during the middle stage ((**a**), approximately 20 d after the short-day and low-temperature treatment) and late stage ((**b**), approximately 35 d after the short-day and low-temperature treatment). Vertical bars indicate standard errors of the means (n = 15).

Furthermore, we investigated the aerial and root fresh weight of the plantlets according to the treatment date and calculated the ratio of aerial to root part biomass (T/R) (Figure 3). Greater root weight indicates superior root development, which is a significant factor determining the yield of plantlets [1]. In the present study, the T/R ratio tended to decrease in the late-nursery stage compared to that in the mid-nursery stage, indicating increased root growth in the plantlets. The decline in the T/R ratio was most pronounced in the 4 July treatment, where the T/R ratio in the late-nursery stage was reduced by 46% in 'Altaking', 35% in 'Jukhyang', 25% in 'Kingsberry', 18% in 'Vitaberry', 16% in 'Kuemsil', and 4% in 'Sulhyang' compared to that in the mid-nursery stage. This indicates that vigorous root development occurred in plantlets in the 4 July treatment.

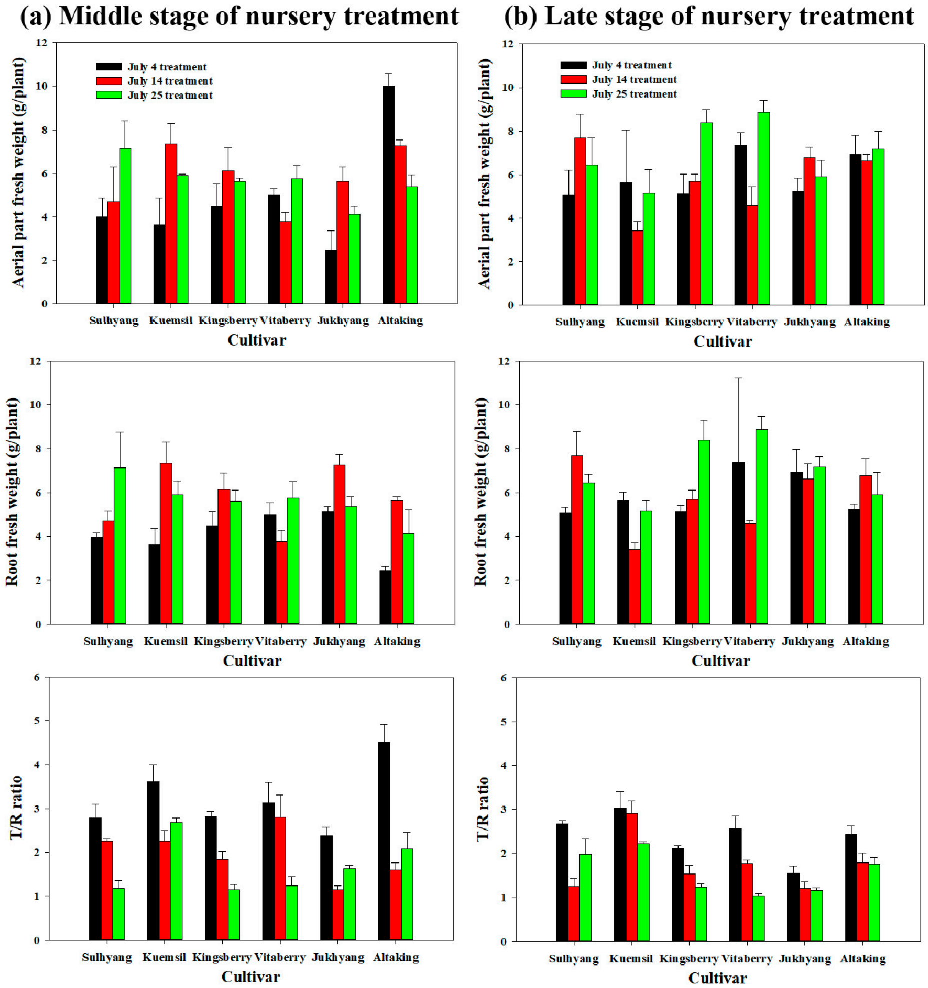

Figure 3. Fresh weight of aerial and root parts and top/root ratio of six strawberry cultivars in the nursery period affected by the short-day and low-temperature treatment (three treatment start dates: 4 July, 14 July, and 25 July) during the middle stage ((**a**), approximately 20 d after the short-day and low-temperature treatment) and late stage ((**b**), approximately 35 d after the short-day and low-temperature treatment). Vertical bars indicate standard errors of the means (n = 15).

3.2. Inflorescence and Harvest Characteristics

We investigated the first flower cluster budding and flowering times of strawberries after the short-day and low-temperature treatments, depending on the treatment date (Figure 4). After the short-day and low-temperature treatment, representative June-bearing 'Sulhyang' cultivars [20] exhibited an earlier flowering period, with the first flower starting to flower on 19 September, 40 d earlier than the control group, in which flowering started on 28 October. The first flower cluster budding and flowering times of all six cultivars differed between the short-day and low-temperature treatment and the control groups. 'Altaking' had the earliest first flower cluster budding and flowering, whereas 'Jukhyang' and 'Kuemsil' had the latest. When the 14 July nursery treatment started, 'Sulhyang' and 'Altaking' exhibited the earliest first flower cluster budding on 12 September and flowering on 19 September, with 'Vitaberry', 'Kingsberry', 'Jukhyang', and 'Kuemsil' flowering later in the same sequence. When the 14 July treatment started, with the plants transplanted on 18 August, 'Altaking' showed the first flower cluster budding and flowering on 12 September and 19 September, respectively. 'Sulhyang' and 'Vitaberry' flowered at the same times, followed by 'Kingsberry', 'Kuemsil', and 'Jukhyang'. When the 25 July treatment started, with the plants transplanted on 25 August, 'Altaking' showed budding with the first flower cluster on 23 September and flowering on 27 September, with 'Sulhyang', 'Vitaberry', 'Kingsberry', 'Kuemsil', and 'Jukhyang' following in that order for both the first flower cluster budding and flowering. In the control group, 'Altaking' had the earliest budding and flowering dates on 10 October and 24 October, respectively. Budding and flowering occurred at the same period in 'Sulhyang', 'Kingsberry', and 'Vitaberry', whereas 'Kuemsil' and 'Jukhyang' had the latest budding and flowering times. This is consistent with previous studies showing that the dormancy and photoperiod-induced flower induction differ depending on different strawberry cultivars [21–23]. It was confirmed that carrying out the short-day and low-temperature treatment for the nursery stage on 4 July and transplanting on 11 August promoted budding and flowering compared to the control group. By promoting flower bud differentiation, the early yield of strawberries increases, which can improve farm income [24,25]. Hence, normal initiation and differentiation of the first flower cluster occurred during the high-temperature period.

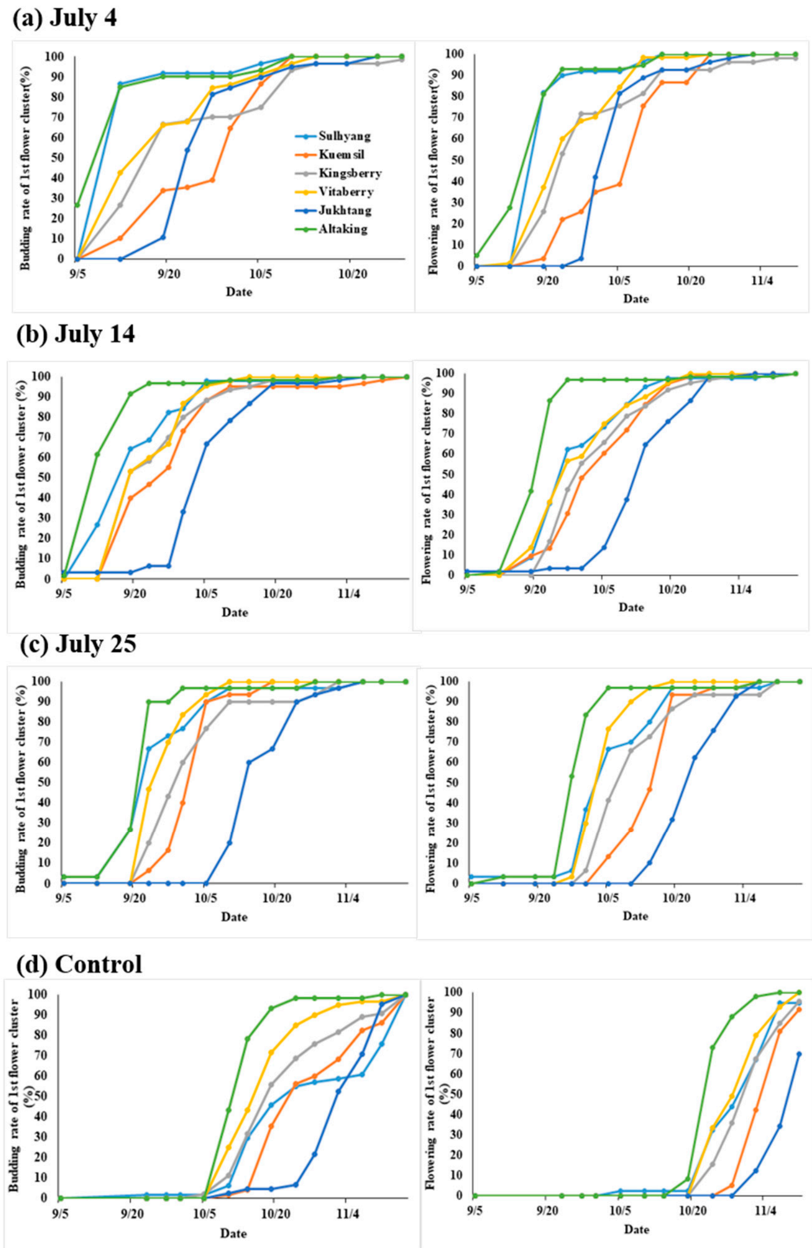

Figure 4. Changes in the budding and flowering rates of six strawberry cultivars in the first flower cluster affected by the short-day and low-temperature treatment (three treatment start dates: 4 July, 14 July, and 25 July) and the control.

Furthermore, we investigated the first flower cluster harvest rate of first strawberries after the short-day and low-temperature treatments, depending on the treatment date (Figure 5). When the 4 July treatment started, the first harvest date of 'Altaking' was 30 September, which was the earliest among the varieties. The harvest date of 'Sulhyang' was on 10 October, whereas 'Kuemsil', 'Kingsberry', and 'Vitaberry' were harvested on 19 October. 'Jukhyang' was the last, with the first harvest date on 25 October (Figure 6). Compared to the control group transplanting on 15 September, the first fruits of 'Altaking' were harvested 60 d earlier, those of 'Jukhyang' were harvested 56 d earlier, those of 'Sulhyang' were harvested 50 d earlier, those of 'Kuemsil' were harvested 48 d earlier, and those of 'Kingsberry' and 'Vitaberry' were harvested 41 d earlier. The strawberry market experiences significant price fluctuations based on the time of harvesting [26]; by implementing a short-day and low-temperature treatment during nursery cultivation, the first harvest can be advanced by approximately 2 months, increasing the income through increasing market prices. The first-cluster harvesting time shifted based on the transplanting date. In the case of 'Sulhyang', after the 4 July treatment, the first flower cluster harvesting occurred on 19 October; in the 14 July treatment, it occurred on 25 October; in the 25 July treatment, it occurred on 1 November; and in the control group with transplanting on 15 September, it occurred on 27 December. After the short-day and low-temperature treatment on 4 July, harvesting could be maximally promoted by transplanting on 11 August. Therefore, it is deemed most advantageous to transplant on 11 August to obtain a higher price of strawberries.

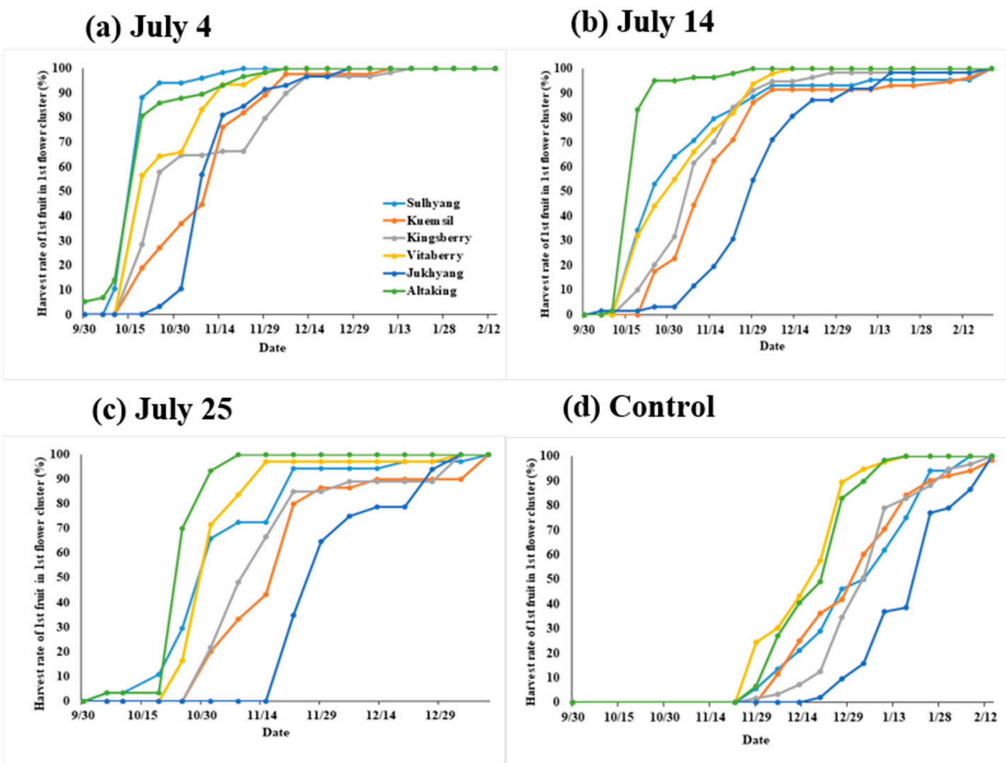

Figure 5. Changes in the first fruit harvest rate of six strawberry cultivars in the first flower cluster affected by the short-day and low-temperature treatment (three treatment start dates: 4 July, 14 July, and 25 July) and control.

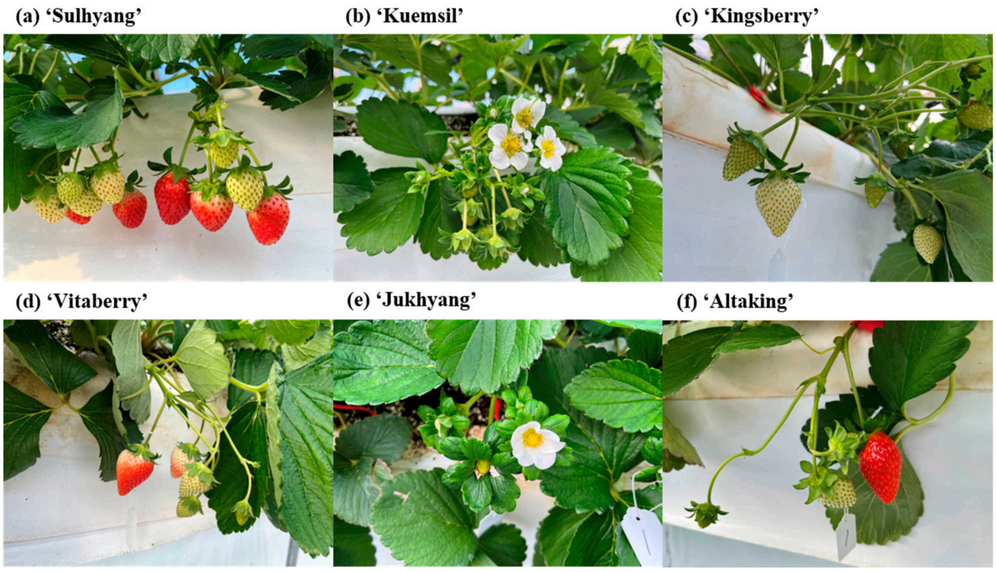

Figure 6. Fruits of six strawberry cultivars in the first flower cluster affected by the short-day and low-temperature treatment (treatment start date 4 July) on 13 October 2022.

3.3. Yield Characteristics

We investigated the marketable yield for the off-season strawberries in Korea from October to December based on the date of the short-day and low-temperature treatment (Figure 7). For the 'Sulhyang' cultivar, the marketable yield in October was highest when transplanted on 11 August after nursery treatment on 4 July, with 68.6 g per plant. Treatment on 14 July resulted in 25.2 g per plant, while treatment on 25 July showed minimal production at 1.8 g per plant. The control group had its first harvest on 15 November, with no yield in October. It is considered that treatment on 14 July can enhance income through higher strawberry prices. For the different cultivars treated on 4 July, the October marketable yields were as follows: 'Kuemsil' 16.2 g, 'Kingsberry' 32.3 g, 'Vitaberry' 22.7 g, 'Jukhyang' 0.3 g, and 'Altaking' 31.8 g. 'Jukhyang' had the latest first harvest among the six cultivars on 25 October, consistent with previous research indicating its late flowering and harvesting. 'Jukhyang' is a high-quality cultivar with high sugar content and firmness, commanding a higher price. If an earlier harvest of 'Jukhyang' is desired, it is advisable to perform the short-day and low-temperature treatment on 4 July to induce flowering and transplant as early as possible. There was a tendency towards lower yield in October to December as the treatment date is delayed, except for 'Vitaberry' and 'Altaking', which showed an increase in yield with a later treatment date. The October production for both cultivars increased by 12% and 90%, respectively, when treated on 14 July relative to on 4 July. Despite a slower initial harvest, these cultivars exhibit vigorous plant growth, resulting in increased yield. Although the November production for both cultivars was the highest when treated on 25 July, the October price was approximately 30% higher than the November price. Therefore, for 'Vitaberry' and 'Altaking', the short-day and low-temperature treatment on 14 July is considered advantageous for enhancing farm income.

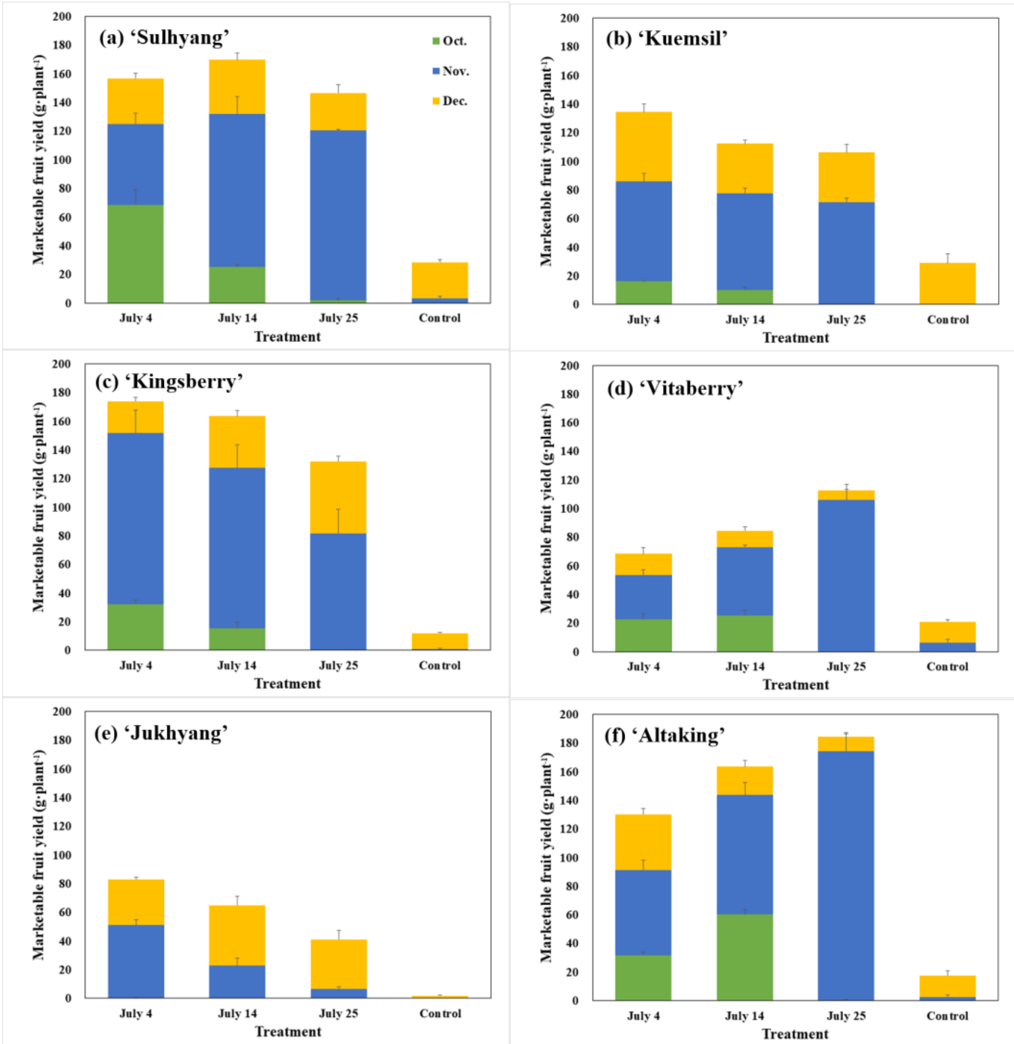

Figure 7. Marketable fruit yield of six strawberry cultivars from October to December based on the date of the short-day and low-temperature treatment (three treatment start dates: 4 July, 14 July, and 25 July) and the control. Vertical bars indicate standard errors of the means (n = 3).

We investigated the fruit weight and yield for each flowering cluster according to the treatment date for each cultivar (Table 3). In all treatment groups, 'Altaking' showed the highest marketable fruit yield and marketable fruits ratio. 'Sulhyang', 'Kingsberry', and 'Altaking' are considered suitable cultivars for accelerated forcing culture due to their rapid flowering and high productivity. In all treatments, including the control, the marketable fruit yield of 'Jukhyang' was the lowest. In the 4 July treatment, its marketable fruit yield was 335.5 g/plant, being 120%, 104%, 72%, 45%, and 36% lower than those of 'Altaking', 'Kingsberry', 'Sulhyang', 'Kuemsil', and 'Vitaberry', respectively. In the 14 July treatment, its marketable fruit yield was 381.7 g/plant, being 141%, 80%, 64%, 21%, and 12% lower than those of 'Altaking', 'Kingsberry', 'Sulhyang', 'Vitaberry', and 'Kuemsil', respectively. In the 25 July treatment, its marketable fruit yield was 395.2 g/plant, being 121%, 71%, 54%, 33%, and 22% lower than those of 'Altaking', 'Sulhyang', 'Kingsberry', 'Vitaberry', and 'Kuemsil', respectively. In the control treatment without a nursery treatment, with the plants transplanted on 15 September, the marketable fruit yield of 'Jukhyang' was 315.7 g/plant, being 122%, 95%, 59%, 28%, and 11% lower than those of 'Altaking', 'Kingsberry', 'Sulhyang', 'Kuemsil', and 'Vitaberry', respectively. The 'Jukhyang' cultivar exhibits late flowering and harvesting and a high production of small fruits (less than 12 g), leading to a decrease in marketable yield and a lower marketable yield ratio.

Table 3. Yield characteristics of six strawberry cultivars affected by the short-day and low-temperature treatment (three treatment start dates: 4 July, 14 July, and 25 July) and control.

Treatment [z]	Cultivar	Marketable Fruit Yield (g/Plant)	Yield (kg/m^{-2})	Marketable Fruit Ratio (%)
4 July	Sulhyang	576.9 ef [y]	5.55 ef	82.7 a
	Kuemsil	485.4 g–i	4.67 g–i	80.0 a
	Kingsberry	684.5 b–d	6.59 b–d	80.2 a
	Vitaberry	456.3 g–j	4.39 g–i	79.4 a
	Jukhyang	335.5 lm	3.23 lm	65.1 b
	Altaking	797.5 b	7.09 b	83.2 a
14 July	Sulhyang	627.5 c–e	6.04 c–e	83.8 a
	Kuemsil	427.5 h–k	4.11 h–k	78.4 a
	Kingsberry	685.4 b–d	6.59 b–d	78.2 a
	Vitaberry	461.1 g–j	4.44 g–j	77.9 a
	Jukhyang	381.7 j–m	3.67 j–m	67.7 b
	Altaking	921.5 a	8.86 a	84.6 a
25 July	Sulhyang	676.9 b–d	6.51 b–d	82.7 a
	Kuemsil	484.0 g–i	4.66 g–i	78.8 a
	Kingsberry	608.2 de	5.85 de	77.4 a
	Vitaberry	526.2 f–g	5.06 f–g	82.9 a
	Jukhyang	395.2 j–m	3.80 j–m	61.9 b
	Altaking	871.8 a	8.39 a	83.4 a
Control	Sulhyang	500.5 f–h	4.82 f–h	79.9 a
	Kuemsil	403.8 i–l	3.88 i–l	76.2 a
	Kingsberry	614.9 de	5.92 de	82.3 a
	Vitaberry	351.8 k–m	3.38 k–m	68.6 b
	Jukhyang	315.7 m	3.04 m	64.5 b
	Altaking	702.1 b–c	6.75 bc	84.3 a

[z] The short-day and low-temperature treatment start dates: 4 July, 14 July, and 25 July; [y] mean separation within columns by DMRT at a 5% level. Different lowercase letters indicate significant differences ($p < 0.05$) between treatments.

Furthermore, the yield of each flowering cluster was investigated (Figure 8), and the results showed that for the 'Sulhyang' cultivar, the yield per each flower cluster increased in all flower clusters after the nursery treatment compared to the control group. 'Kuemsil' showed a high overall yield in the 4 July and 25 July treatments, especially in the former, where it had a relatively uniform fruit production without significant variation after the sixth flower cluster and was 20% higher in yield compared to the control group transplanted on 15 September. In the 4 July and 14 July treatments, the yield of 'Kingsberry' was 11% higher than that of the control group transplanted on 15 September. Transplanting on 11 August after the short-day and low-temperature treatment on 4 July is deemed effective for enhancing income, as the initial yield in the first to fifth flower clusters was high, leading to an increase in strawberry price. In the 25 July treatment, 'Vitaberry' showed the highest total marketable yield per plant at 526.2 g, but consistent development was observed in the later flower clusters when treated on 4 July and 14 July. When treated with the short-day and low-temperature treatment during the nursery stage, 'Jukhyang' exhibited significantly higher yield in the first flower cluster compared to the control group. This is expected to contribute to income enhancement for farmers. 'Altaking' had the highest yield in the 14 July treatment (921.5 g/plant) and consistently showed a high yield from the beginning to the late yield, resulting in a 31% higher yield compared to that of the control group. This was consistent with the findings of previous research showing an increase in yield and marketable fruit ratio in short-day and low-temperature treatments compared to those in the control [27].

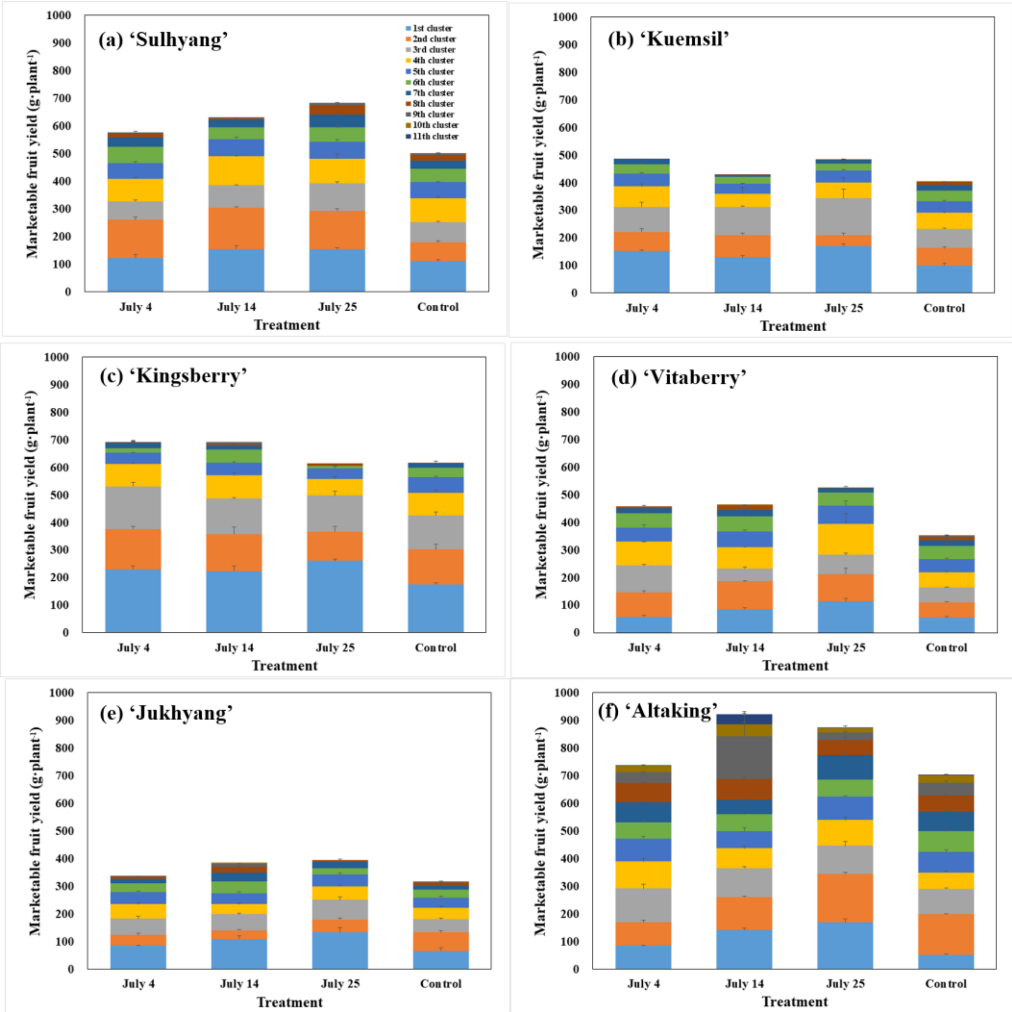

Figure 8. Marketable fruit yield of six strawberry cultivars by flower clusters affected by the short-day and low-temperature treatment (three treatment start dates: 4 July, 14 July, and 25 July) and the control. Vertical bars indicate standard errors of the means (n = 3).

3.4. Fruit Quality Characteristics

We examined the quality characteristics of the harvested fruits (Figure 9). In October, the sugar content (Brix) of the fruits was the highest at 12.2 °Bx for 'Kuemsil' in the 4 July treatment, and in November, it was the highest at 12.5 °Bx for 'Jukhyang' in the 4 July treatment. Due to the delayed first harvest of the 'Jukhyang' cultivar, the quality of fruits in October could not be investigated. In February, which is the winter season, 'Kuemsil' and 'Jukhyang' in the 4 July treatment had the highest sugar contents at 13.3 °Bx, and 'Kingsberry', transplanted on 15 September, had the lowest sugar content at 7.9 °Bx. In July, the sugar content was the highest for 'Jukhyang' in the 4 July treatment at 13.6 °Bx. Therefore, 'Jukhyang' exhibited high sugar content characteristics under both low- and high-temperature periods. The average sugar content of the six cultivars was 11.2 °Bx in October, 11.6 °Bx in November, 10.9 °Bx in February, and 10.3 °Bx in July. The average sugar content in July was 11% lower than that in November, but it was within an acceptable range without a significant decrease in fruit quality. By managing appropriate temperature conditions and day-length control in the high temperature period, it is possible to extend the cultivation schedule until July, thereby improving the productivity of marketable fruits. While 'Kuemsil' and 'Jukhyang' may not be ideal cultivars for accelerated forcing culture due to late flowering and harvesting, they have the advantage of high sugar content, allowing for higher selling prices for high-quality fruits. Particularly, 'Kuemsil', which is not a cultivar with robust root growth, would benefit from managing the root development by maintaining the root zone temperature at the optimal range of 18–20 °C, contributing to increased productivity. The firmness of fruits harvested in October was the highest for 'Kuemsil' in the 14 July treatment (23.8 g/mm^2), or 44% higher than that of 'Sulhyang' in the same treatment. In November, the fruit firmness for 'Vitaberry' in the 4 July treatment was 21.5 g/mm^2, and in the winter season (February), this cultivar showed the highest firmness among the six cultivars (average of 20.5 g/mm^2). In the summer, fruit firmness decreases because of the high-temperature greenhouse environment. In the July 25 treatment, 'Sulhyang' and 'Altaking' had the lowest fruit firmness at 10.8 g/mm^2, which is 22% lower than that of 'Kuemsil' in the same treatment. The fruits produced in July have small sizes and low firmness, but they possess qualities suitable for decorative purposes, making them in demand for use in cafes and bakeries. Therefore, cultivars such as 'Sulhyang', 'Kingsberry', and 'Altaking', which have low firmness, can be utilized effectively in such applications. Fruits produced in July had a low sugar–acid ratio as one of the factors determining fruit quality. In October, the sugar–acid ratio of the fruits was the highest for 'Kuemsil' in the 4 July treatment (19.3), whereas 'Kingsberry' had a sugar–acid ratio of 13.8, which is 28% lower than that of 'Kuemsil'. 'Kuemsil' exhibited excellent quality characteristics in terms of sugar content, firmness, and the sugar–acid ratio, all of which are parameters related to fruit quality. In November, 'Kuemsil' of the 14 July treatment had the highest sugar–acid ratio of 21.5. The sugar–acid ratio is one of the factors determining fruit quality. In October, the sugar–acid ratio of the fruits was the highest for 'Kuemsil' in the 4 July treatment (19.3), whereas 'Kingsberry' had a sugar–acid ratio of 13.8, which is 28% lower than that of 'Kuemsil'. In November, 'Kuemsil' in the 14 July treatment had the highest sugar–acid ratio of 21.5. In the low-temperature season in February, the average sugar–acid ratio for all six cultivars in the 4 July treatment was 21.1, which is 15% higher than that of the control (18.4); this indicates that the short-day and low-temperature treatment resulted in a higher sugar–acid ratio and high-quality fruit. In the high-temperature season of July, the average sugar–acid ratio of all six cultivars in the 4 July treatment was 11.7, which is 80% lower than that in February. However, considering the marketable quality, it is expected that the product quality will be maintained during the high-temperature period in July, making it suitable for sale. The key factors affecting year-round strawberry production are continuous flowering and fruit quality during the high-temperature period [26]. Our results show that even when the harvest season is advanced by a short-day and low-temperature treatment, high-quality fruits can be produced. However, the quality of fruits produced in the high-temperature season of October and July is expected to be lower than that in the low-temperature period. Therefore, to enhance marketability, ongoing environmental management, such as continuous cooling, shading, and fogging, will be necessary even after transplanting to lower the temperature.

Figure 9. Fruit quality characteristics of six strawberry cultivars affected by the short-day and low-temperature treatment (three treatment start dates: 4 July, 14 July, and 25 July) and the control (investigation date: (**a**), October 2022; (**b**), November 2022; (**c**), February 2023; (**d**), July 2023). Vertical bars indicate standard errors of the means (n = 15).

4. Conclusions

Korea's forcing culture of strawberries involves planting plantlets that have completed flower induction in September, with harvesting starting at the end of November and concluding in May. To harvest fruits in the off-season month of October, artificial flower differentiation was induced during the nursery stage using greenhouse environmental control facilities. An experiment was conducted using a total of six cultivars, namely 'Sulhyang', 'Kuemsil', 'Kingsberry', 'Vitaberry', 'Jukhyang', and 'Altaking'. The goals of this experiment were to find a cultivation schedule for off-season production and select the most suitable Korean strawberry cultivars for both off-season and high-temperature production. Results from initiating night-chilling nursery treatment on 4 July, 14 July, and 25 July revealed that treating on 4 July for approximately 5 weeks, followed by transplanting on 11 August, resulted in the highest production in October. Considering the higher strawberry prices in October, it is deemed advantageous for increasing farm income. However, to maintain a low-temperature environment in the greenhouse from 4 July to 11 August, cooling facilities and light-blocking installations are necessary. Essential additional equipment includes the cost of installing cooling facilities, electricity expenses, and structures for light-blocking facilities. It is determined that the introduction of cost-effective and energy-efficient cooling facilities and the widespread application of related technologies are needed. The six Korean cultivars used in the experiment exhibit high sugar content but generally have low firmness. Cultivars such as 'Sulhyang', 'Altaking', and 'Kingsberry' are suitable for accelerated forcing culture due to their rapid flowering and high yield. However, since the fruit quality declines in high-temperature conditions, maintaining a low-temperature environment through facilities such as cooling and shading is necessary even after transplanting. Cultivars like 'Kuemsil' and 'Jukhyang' flower late and have lower yields, but possess high sugar content and firmness. For farmers interested in cultivating these cultivars, starting early with mother plant cultivation, adjusting the nursery schedule, and ensuring robust plantlet development before transplanting is recommended. Particularly, the 'Kuemsil' cultivar requires proper post-transplanting management in the root zone environment. The adoption of the developed cultivation schedule and selected cultivars from this study is expected to enhance strawberry yield in high-temperature and off-season conditions, contributing to increased farm income (Figure 10).

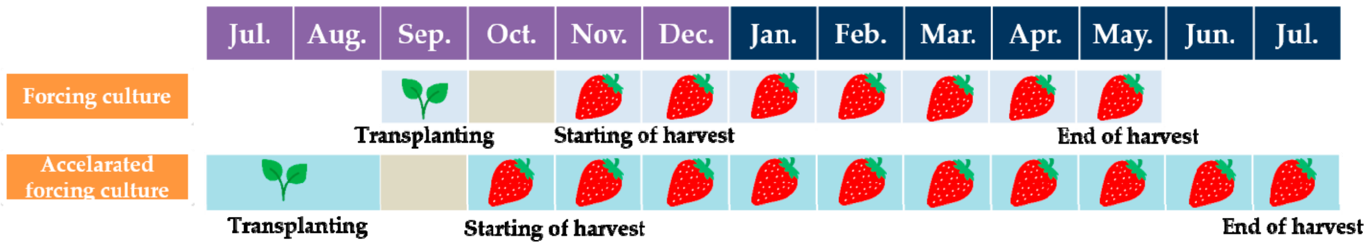

Figure 10. Comparison of forcing culture and accelerated forcing culture using the short-day and low-temperature treatment.

Author Contributions: Investigation, S.-H.C.; Supervision, D.-Y.K.; Writing—original draft, S.-H.C.; Writing—review and editing, S.K. and C.S.G. All authors have read and agreed to the published version of the manuscript.

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