horticulturae

MDPI

Article

The Effect of Replacing Peat with Sugarcane Bagasse on the Growth of Cut Flowers and Bulbs of Lily

Guangfen Cui [1,2,3,4,5], Wenwen Du [1,2,3,4,†], Qing Duan [1,2,3,4], Xiang Li [1,2,3,4], Lan Ma [1,2,3,4] and Jihua Wang [1,2,3,4,*,†]

1 Flower Research Institute, Yunnan Academy of Agriculture Sciences, Kunming 650205, China; cuiguangfen@126.com (G.C.); wenwendu2014@hotmail.com (W.D.); duanqing123@126.com (Q.D.); leexiang93@163.com (X.L.); malan123203@163.com (L.M.)
2 Seed Industry Joint Laboratory of Yunnan Province, Kunming 650205, China
3 National Engineering Research Center for Ornamental Horticulture, Kunming 650205, China
4 Yunnan Flower Technology Innovation Center, Kunming 650205, China
5 Research Institute of Agro-Products Processing, Yunnan Academy of Agriculture Sciences, Kunming 650221, China
* Correspondence: otlily@163.com
† These authors contributed equally to this work.

Abstract: In order to evaluate the feasibility of using sugarcane bagasse (SCB) as a substitute for peat in lily cultivation, this study examines the effects of replacing different amounts of peat (0%, 25%, 50%, 75%, and 100%) with SCB on the physical and chemical properties of the substrate. The impact on the growth of cut flower and bulbs of the oriental lily variety 'Siberia' was investigated. The results show that the pH value, organic matter content, and reducing sugar content of the substrate were significantly increased ($p < 0.05$) when peat was replaced with SCB. Moreover, the bulk density, permeability porosity, water-holding porosity, and EC value, as well as the contents of hydrolyzed nitrogen, available phosphorus, available potassium, exchangeable calcium, and exchangeable magnesium were significantly decreased ($p < 0.05$). The bulk density (0.15–0.17 g·cm^3), total porosity (64.2–69.6%), and water-holding porosity (41.0–48.4%) of the mixed media were in a suitable range. The addition of SCB led to shorter plant height, a thinner stalk, and a smaller leaf and flower diameter. The contents of total chlorophyll, chlorophyll a and b in leaves, as well as the activities of sucrose synthetase (SS) and sucrose phosphate synthetase (SPS) decreased with the increase in SCB in the substrates at different growth stages of lily cut flowers. The correlation analysis showed that, except for bulb height, other quality traits of cut flowers and bulbs were significantly negatively correlated with the pH, organic matter, and reducing sugar content of substrates. Plant height, stem diameter, leaf number, leaf length and width, flower diameter of cut flowers, as well as the fresh weight, starch content, the activities of SS and SPS of bulbs were significantly positively correlated with the bulk density, total porosity, water-holding porosity, and hydrolyzed N content of substrates ($p < 0.05$). The load factors of the principal components indicated that the diameter of stem and flower, leaf number, the content of chlorophyll a and b, and total chlorophyll of cut flowers and SPS activity in bulbs could be used as the core indicators for evaluating the suitability of lily cultivation substrate. In conclusion, when the proportion of peat replaced with SCB was lower than 50%, the quality of cut flowers and bulbs was the same as that found with whole peat. Thus, SCB has broad application prospects in the soilless cultivation of lily plants.

Keywords: sugarcane bagasse; peat; cultivation substrate; lily; cut flower

Citation: Cui, G.; Du, W.; Duan, Q.; Li, X.; Ma, L.; Wang, J. The Effect of Replacing Peat with Sugarcane Bagasse on the Growth of Cut Flowers and Bulbs of Lily. *Horticulturae* **2024**, *10*, 1132. https://doi.org/10.3390/horticulturae10111132

Academic Editor: Maria Roulia

Received: 29 August 2024
Revised: 7 October 2024
Accepted: 17 October 2024
Published: 24 October 2024

1. Introduction

Soilless cultivation techniques find great success with ornamental plants. Compared to soil cultivation, soilless cultivation can greatly expand agricultural production space, obtaining high yield and a fast harvest with smaller unit production areas [1,2]. It also permits a more efficient use of water and fertilizer; reduces the use of pesticides, herbicides, and other chemicals in the planting process; and effectively controls non-point source pollution [3]. The traditional cultivation method used to grow lilies, one of the most sought-after cut flowers in the world, is soil cultivation. However, with long-term high-intensity repeated planting, the obstacles of continuous cropping are becoming increasingly significant, and the quality of cut lily flowers is decreasing [4]. Therefore, in European countries with developed flower industries, almost all cut lily flowers are grown via soilless cultivation. Peat is the most widely used substrate in the soilless cultivation of lilies [5].

Peat is a natural deposit formed by plant decay residue. It has an ash content of less than 10%, and the advantages of uniform composition, high moisture retention, good ventilation, and a stable structure. Commercial peat mainly comes from Europe and Canada. Peat is defined as a non-renewable resource; it takes several thousand years to form, and great ecological damage is caused by its exploitation [6]. In order to reduce dependence on peat, various agricultural residues and inorganic substrates have been investigated for the soilless cultivation of horticultural crops. Through the evaluation of the physical properties of biochar, as well as inorganic substrates of various organic agricultural residues, it has been proven that wheat straw, sawdust, coconut chaff, rock wool, and other materials can be used as improvements to or substitutes for commercial growth media [7–9]. Many substrates have been tested to replace peat in the soilless cultivation of lilies, including organic agricultural waste such as straw, corn stalks, mushroom residue, bean pods [10], palm pomace, and coconut chaff [11], and inorganic substrates such as river sand, perlite, vermiculite, and volcanic tuff [10,12]. Various substrates with different compositions have shown certain effects.

Sugarcane bagasse (SCB) is a by-product of the sugar industry, composed primarily of cellulose (32–45%), hemicellulose (20–32%), lignin (17–32%), and ash (1.0–9.0%) [13]. It is often used as a material for the production of biofuels, such as ethanol [14], butanol [15], xylitol [16], enzymes [17], and feed [18]. SCB has a considerable yield and has been successfully used to improve substrates for the soilless cultivation of crops such as cucurbit seedlings, tomato, and *Osteospermum* [19–21]. Because of its renewable nature and the increasing demand for soilless cultivation substrates in modern agriculture, there is great potential for the application of SCB as a soilless substrate.

To evaluate the feasibility of using SCB as a substrate for the soilless cultivation of cut lily flowers, the effects of the SCB content on the growth and related quality indicators of cut lily flowers and post-flower bulb development were analyzed for different replacement ratios of SCB.

2. Materials and Methods

2.1. Plant Materials and Substrates

The oriental lily cultivar 'Siberia' was used for the experiment. The specimens were first-generation bulbs with a circumference of 12–14 cm from the Van Den Bos Flowerbulbs B.V., Honselersdijk, Netherlands. The peat was imported from Pindstrup Mosebrug A/S, Ryomgaard, Denmark, with a particle size of 10–30 mm. SCB was purchased from a local market in Yunnan Province, China.

2.2. Experimental Design

The test site was located in Kunming, Yunnan Province, China (north latitude, 24°54′17″; east longitude, 102°46′24″; altitude, 1866.8 m), and the planting date of the lily bulbs was 19 June 2023. The cultivation facility is a fully automatic intelligent control greenhouse with a minimum temperature of 15 °C and a maximum temperature of 26 °C. The relative air humidity is 70%, and the light intensity is 10,000–25,000 Lux. Five substrate treatments were set up based on SCB content, namely T1, T2, T3, T4, and T5. The T1 treatment consisted of whole peat and was set as the control group (CK). The substrate composition ratio of each treatment is shown in Table 1. The cultivation suitability of lilies to SCB was evaluated by recording the key growth indicators of lilies on different SCB content substrates. Three replicates were established for each treatment, and 50 lily bulbs were planted in each replicate. The bulbs were planted in special planting boxes (40 cm × 60 cm × 20 cm), with 10 bulbs per box. After planting the bulbs in the substrate, drip irrigation was performed three times a day. The irrigation system adopted an integrated water and fertilizer model. The matrix test design scheme is shown in Table 1.

Table 1. Composition of the substrate treatments (%, in volume).

Substrate Component	T1 (CK)	T2	T3	T4	T5
Peat (%)	100	75	50	25	0
SCB (%)	0	25	50	75	100

2.3. Determination of Physical and Chemical Characteristics of Substrate

The physical and chemical parameters of the media measured in this study included pH value, electrical conductivity (EC), bulk density, total porosity, aeration porosity, water-holding porosity, the content of organic matter, hydrolytic N, available P, available K, exchangeable Ca, exchangeable Mg, and reducing sugar.

(1) Determination of pH and EC: The fresh sample was mixed with deionized water at a ratio of 1:10 (*v*:*v*) and the supernatant was filtered after 30 min of oscillation. The pH value and EC value of the supernatant were determined by a pH meter and conductivity meter, respectively.

(2) Method for the determination of bulk density, total porosity, aeration porosity, and water-retention porosity: Weigh the beaker (W1), then fill it with the naturally dried substrate to be measured (W2). Seal the beaker filled with the substrate with two layers of gauze. Soak it in water for 24 h, and then take out the substrate and weigh it (W3). At the same time, weigh the two layers of wet gauze used for sealing (W4). After weighing, wrap the beaker upside down with two layers of wet gauze. Then, let the water in the beaker drain freely until no water seeps out. Weigh it again (W5). V represents the volume of the dried substrate. The following formulae are used for calculations:

$$\text{Bulk density (g/cm}^3\text{)} = (\text{W2} - \text{W1})/\text{V}; \quad (1)$$

$$\text{Total porosity (\%)} = (\text{W3} - \text{W2})/\text{V} \times 100; \quad (2)$$

$$\text{Aeration porosity (\%)} = (\text{W3} + \text{W4} - \text{W5})/\text{V} \times 100; \quad (3)$$

$$\text{Water-holding porosity (\%)} = \text{Total porosity} - \text{Aeration porosity}. \quad (4)$$

(3) Determination of the main fertilizer ingredients: Hydrolyzed N, available P, and available K were determined by the alkaline hydrolysis diffusion method, phospho-vanado-molybdate colorimetry, and flame photometry, respectively. Exchangeable Ca and exchangeable Mg were determined by atomic absorption spectrophotometry, and organic matter determination was carried out using carbon and nitrogen analysis instruments [9]. The reducing sugar content was determined by 3,5-dinitrosalicylic acid colorimetry [10].

2.4. Determination of Growth Indicators for Cut Flowers and Bulbs

Plant height (the distance between the root neck and the top of the flower branch), stem diameter (diameter of the middle stem of the plant), number of leaves, leaf length and width (the eighth leaf down from the top of the plant), flower diameter (diameter of the first flower in the plant) during the flowering period, and the circumference (the maximum circumference of the bulb), fresh weight, and height of the new bulbs after harvesting were measured.

2.5. Physiological Indicators of Cut Flowers and Bulbs

The middle leaves of the lily plants were collected at the bud stage (with a flower bud length of 1.0 cm), the flowering stage (with the first flower blooming), and the 15th, 30th, 45th, and 60th days after the last flower withered to measure the content of chlorophyll a, chlorophyll b, and total chlorophyll. The chlorophyll content was determined by spectrophotometry. Then, 1 mL N, N-dimethylformamide was added to the sample and extracted in the dark for 8 h. The optical density of the supernatant after centrifugation was measured by a spectrophotometer at 665 nm and 649 nm. Then, the chlorophyll a and chlorophyll b contents and total content were calculated [22].

The activities of sucrose synthetase (SS) and sucrose phosphate synthetase (SPS) were measured on the 15th, 30th, 45th, and 60th days after flowering, considering the 8th leaf from the top of the plant. The determination of SS and SPS followed the method used for cucumber seedlings in [23]. For SS detection, take 0.35 mL of reaction solution and add 0.2 mL of enzyme solution to react at 37 °C for 30 min. Then, immerse the reaction solution in a water bath at 100 °C for 1 min, and continue adding NaOH to the reaction solution for another 10 min. Finally, after adding HCl and resorcinol, place the mixture in an 80 °C water bath for 10 min. The activity value of the mixture was calculated after colorimetric analysis at 480 nm. For the SPS reaction system, 6-phosphate fructose was used instead of fructose, but the other determination methods were the same as for SS.

The starch content of new bulbs after harvesting was determined by the enzymatic method [24]. Samples were treated with 40% ethanol to remove any soluble sugar, and the precipitate was added to dimethyl sulfoxide to form a uniform suspension in a 100 °C water bath for 30 min. After cooling, hydrochloric acid was added and hydrolyzed in a water bath at 60 °C for 30 min. Then, sodium hydroxide and sodium acetate buffer were added, and the pH was adjusted to 4.8 to make a sample solution. Amyloglucosidase (AMG) solution was incubated in a 60 °C water bath for more than 16 h to determine the starch content.

2.6. Statistical Analysis

All data were processed using Excel 2021. Duncan's test was used to test the significance of the differences among the different treatments ($p < 0.05$). One-way ANOVA, correlation analysis, and principal component analysis (PCA) were performed and plotted with Origin Pro Software version 2021 (OriginLab, Northampton, MA, USA). The results are expressed as the mean ± standard deviation (SD). The relationships between the substance parameters and growth indicators of the cut flowers and bulbs were assessed using Pearson's correlation coefficients. Experimental data from each group were obtained in triplicate.

3. Results

3.1. The Physical and Chemical Properties of Substrates Before Planting Lilies

SCB and peat are two different substrates, which are different not only in appearance, but also in physical and chemical properties. The growth status of lilies planted on substrates with different SCB contents showed obvious differences (Figure 1).

When the volume content of SCB was 25% (T2), the physical properties of the mixed substrates were significantly different from that of T1 ($p < 0.05$). As shown in Table 2, replacing peat with SCB significantly reduced the bulk density of the media ($p < 0.05$); moreover, the bulk density also decreased with the increase in the substitution ratio. Compared to the T1 treatment, the bulk density in the T2, T3, and T4 treatments decreased by 10.5%, 15.8%, and 21.1%, respectively. Substituting peat with SCB significantly reduced the aeration porosity, water-holding porosity, and total porosity of the substrate. The total porosity and water-holding porosity in T5 were 7.1% and 5.1% lower than in T1, respectively. The aeration porosity in T5 was 49.1% lower than in T1, indicating that the permeability of peat is much higher than that of SCB, with the addition of SCB having a great impact on the aeration porosity of the substrate.

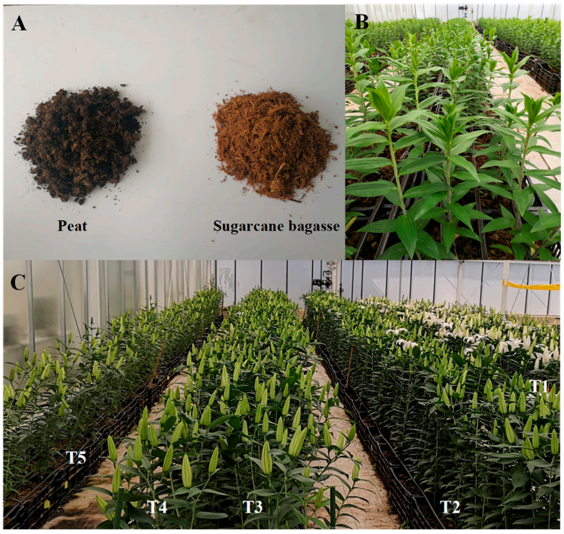

Figure 1. The appearance of peat and SCB, and the growth status of lilies on substrates with different SCB contents ((**A**) is the appearance of peat and SCB; (**B**) shows the seedling status of lilies on T3 substrate with 50% SCB; (**C**) shows the pre-flowering status of lilies on five substrates, each substrate number corresponds to a column of lilies).

Table 2. Physical properties of the substrates based on peat and SCB in different proportions.

Treatment	Bulk Density (g cm^3)	Total Porosity (%)	Aeration Porosity (%)	Water-Holding Porosity (%)
T1 (CK)	0.19 ± 0.02 a	90.07 ± 1.54 a	6.39 ± 0.13 a	83.68 ± 1.66 a
T2	0.17 ± 0.00 ab	80.56 ± 1.94 b	5.23 ± 0.07 b	75.33 ± 2.01 b
T3	0.16 ± 0.00 b	77.87 ± 2.33 bc	4.30 ± 0.26 c	73.57 ± 2.59 bc
T4	0.15 ± 0.00 bc	73.41 ± 0.64 c	3.85 ± 0.26 c	69.57 ± 0.38 c
T5	0.13 ± 0.00 c	63.68 ± 2.59 d	3.25 ± 0.12 d	60.43 ± 2.48 d

Note: Different letters in the same column indicate significant differences among treatments ($p < 0.05$, $n = 3$).

The chemical properties of the substrates are shown in Table 3. The pH from T1 to T5 ranges from 5.5 to 6.5. The pH value of peat is low; by increasing the proportion of SCB added, the pH value of the mixed substrates gradually increased. The EC value showed a gradual decreasing trend from T1 to T5, with significant differences between the substrates ($p < 0.05$). In terms of the EC value, T1 was 63.92% higher than T5, but T3 and T4 were only 16.50% and 7.98% higher than T5, respectively. Thus, the higher the proportion of SCB added, the greater the decrease in EC value in the substrate. The content of organic matter increased with the increase in the proportion of SCB in the five substrates, but the content of organic matter in T1, T2, and T3 was not significantly different from that in T4 and T5. The content of organic matter in T1 was 10.1% and 12.4% lower than in T4 and T5, respectively. The trend of the reducing sugar content was similar to that of organic matter. As the reducing sugar content of peat was significantly lower than that of SCB, we can deduce that the more SCB added, the higher the reducing sugar content of the mixed substrate. The reducing sugar content in the T2, T3, and T4 substrates was 9.2%, 18.4%, and 31.6% higher than that in T1, respectively.

In terms of substrate fertilizer elements, the contents of hydrolytic N and exchangeable Ca decreased gradually from T1 to T5 among the five substrate treatments, showing significant differences ($p < 0.05$). The hydrolytic N content in T1 was 28.14%, 46.13%, 60.10%, and 163.88% higher than in T2, T3, T4, and T5, respectively. The exchangeable Ca content in T1 was the highest among the five substrates, almost 21 times higher than that in T5, and 136.69%, 177.40%, and 497.19% higher than in T2, T3, and T4, respectively. These results indicate that the exchangeable Ca content in SCB is low. The contents of available P, available K, and exchangeable Mg also decreased with the increase in SCB content. The effective P content in T1 was 1.56, 2.55, 2.73, and 3.13 times as much as in T2, T3, T4, and T5, respectively. The highest content of available K was found in T1, which was 69.41% higher than that in T5. The content of available K in T2, T3, and T4 increased by 18.65%, 14.53%, and 6.29%, respectively, compared to that in T5. There was no significant difference in exchangeable Mg content between T2 and T3, or between the T3 and T5 treatments. The exchangeable Mg content in T4 was only 2.43% higher than that in T5, indicating that the exchangeable Mg content in the mixed substrates was not significantly increased in relation to increases in peat.

Table 3. Chemical properties of the substrates based on peat and SCB in different proportions.

Indicators	T1 (CK)	T2	T3	T4	T5
pH	5.62 ± 0.02 d	5.74 ± 0.03 cd	5.88 ± 0.03 bc	5.93 ± 0.05 b	6.38 ± 0.11 a
EC ($mS{\cdot}cm^{-1}$)	808.67 ± 15.82 a	613.00 ± 13.45 b	574.67 ± 12.58 c	532.67 ± 3.05 d	493.33 ± 10.50 e
Organic Matter (%)	69.50 ± 0.89 b	71.30 ± 3.27 b	73.67 ± 1.87 ab	77.27 ± 2.67 a	79.33 ± 0.95 a
Reducing Sugar ($g{\cdot}kg^{-1}$)	7.57 ± 0.59 d	8.30 ± 0.20 cd	9.03 ± 0.40 bc	10.00 ± 0.10 ab	10.33 ± 0.58 a
Hydrolytic N ($mg{\cdot}kg^{-1}$)	548.00 ± 6.93 a	427.67 ± 3.86 b	375.00 ± 6.93 c	342.33 ± 5.13 d	207.67 ± 5.13 e
Available P ($mg{\cdot}kg^{-1}$)	359.00 ± 8.54 a	230.00 ± 8.54 b	141.00 ± 8.89 c	131.33 ± 4.04 cd	114.67 ± 5.69 d
Available K ($mg{\cdot}kg^{-1}$)	2603.33 ± 20.82 a	1823.33 ± 15.28 b	1760.00 ± 36.06 b	1633.33 ± 11.55 c	1536.67 ± 35.12 d
Exchangeable C ($mg{\cdot}kg^{-1}$)	1849.33 ± 21.39 a	781.33 ± 19.04 b	666.67 ± 9.87 c	309.67 ± 16.20 d	89.00 ± 3.61 e
Exchangeable Mg ($mg{\cdot}kg^{-1}$)	454.67 ± 12.01 a	322.67 ± 5.86 b	304.67 ± 4.73 bc	294.00 ± 6.08 c	287.00 ± 6.25 c

Note: Different letters in the same row indicate significant differences among treatments ($p < 0.05$, $n = 3$).

3.2. Chlorophyll Content

Chlorophyll is responsible for the absorption, transfer, and transformation of light energy in plants. Thus, the content of chlorophyll in the leaves is an important indicator of the photosynthetic capacity of plant leaves [25]. The contents of total chlorophyll, chlorophyll a, and chlorophyll b in the leaves of lily cultivar 'Siberia' varied greatly across the different substrates throughout the six growing periods, as shown in Figure 2. The contents of chlorophyll a, chlorophyll b, and total chlorophyll increased rapidly from the bud stage to the flowering stage; decreased after flowering; increased slightly at 45 days after flowering; and decreased rapidly at 60 days after flowering. This was especially evident in T4 and T5. The chlorophyll content of the leaves in the bud stage was the lowest among the six stages. Notably, however, the chlorophyll a content in T1 was 30.00%, 33.00%, 39.17%, and 48.33% higher than in T2, T3, T4, and T5, respectively. The content of chlorophyll b in T3, T4, and T5 was similar at 30 days and 45 days after anthesis, but the content of chlorophyll a in the three substrates was significantly different ($p < 0.05$). This indicates that the total chlorophyll content was more affected by chlorophyll a. At 60 days after flowering, the contents of chlorophyll a and b, and total chlorophyll in T5 decreased by 30.60%, 32.03%, and 31.02% compared to T1, respectively. The difference in chlorophyll content across the six growth stages and the five substrates indicates that the addition of SCB in different proportions reduces chlorophyll content to different degrees.

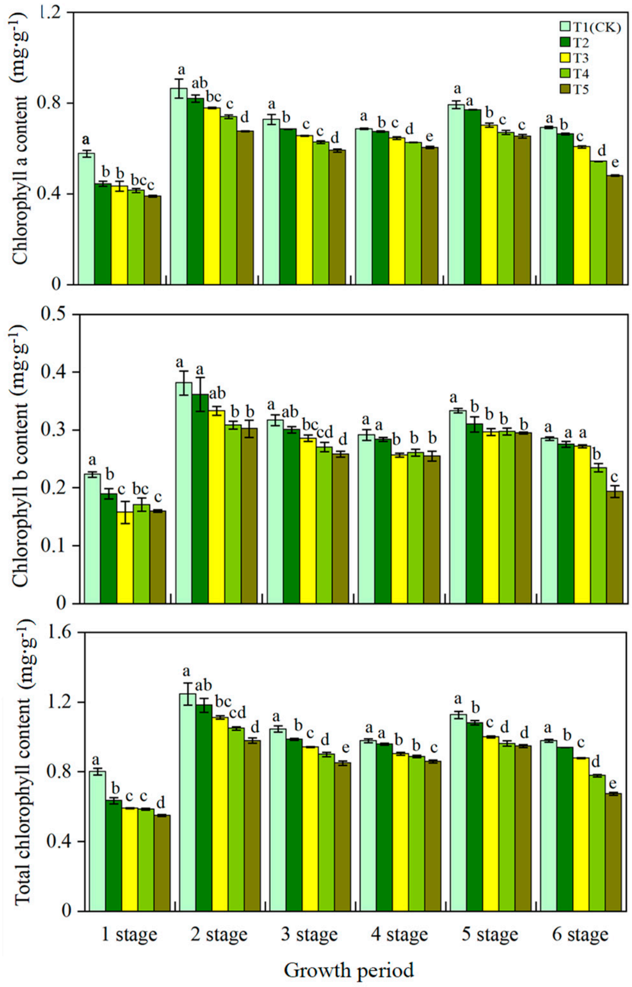

Figure 2. Chlorophyll content in the leaves of the lily cultivar 'Siberia' in 5 substrates based on peat and SCB in different proportions. (Stage 1 refers to the bud stage, stage 2 refers to the flowering stage, and stages 3, 4, 5, and 6 refer to the 15th, 30th, 45th, and 60th days after the flowering stage, respectively.) Chlorophyll content was calculated by fresh weight; its unit indicates fresh weight content. Different letters on the bar chart indicate significant differences among treatments ($p < 0.05$, $n = 3$).

3.3. Morphological Indicators of Cut Flowers

The plant height and stem diameter of lily cut flowers are important quality indexes of stem. It can be seen from Table 4 that, with the increase in SCB in the mixed substrates, the plant height and stem diameter of the cut flowers decreased gradually. The plant heights of the T1, T2, and T3 plants were more than 80 cm, but the plant heights of the T4 and T5 plants were 7.71% and 17.35% lower than in T1, respectively. In addition, the stem diameter in T1 was significantly larger than in T2, T3, T4, and T5, indicating that SCB has a significant negative effect on the plant height and stem diameter of cut flowers. The higher the proportion of SCB, the shorter the plant height of the cut flowers and the thinner the stems. There was no significant difference in the number and length of leaves between T1 and T2. The leaf numbers in T1 were 9.5% and 20.0% greater than in T4 and T5, and the leaf lengths in T1 were 26.9% and 37.2% longer than in T4 and T5, respectively. The leaf widths and lengths across the treatments did not show the same differential characteristics; the leaf widths in T2, T3, and T4 all reached over 6 cm without significant differences. Flower diameter refers to the size of the flower. Compared to T1, the flower diameters in T2, T3, T4, and T5 gradually decreased in sequence. Except for T5, the flower diameters in the treatments were all larger than 22 cm, indicating that SCB could reduce the diameter of cut flowers.

Table 4. Morphological parameters of cut lily flowers in 5 substrates based on peat and SCB in different proportions.

Treatment	Plant Height (cm)	Stem Diameter (mm)	Leaf Number	Leaf Length (cm)	Leaf Width (cm)	Flower Diameter (cm)
T1 (CK)	84.36 ± 1.50 a	6.00 ± 0.14 a	32.4 ± 0.6 a	17.60 ± 0.17 a	7.53 ± 0.25 a	24.72 ± 0.19 a
T2	83.04 ± 1.28 a	5.76 ± 0.17 ab	31.6 ± 0.9 a	16.97 ± 0.35 a	6.57 ± 0.06 b	23.48 ± 0.44 b
T3	81.96 ± 0.83 a	5.48 ± 0.24 b	30.00 ± 0.7 b	15.27 ± 0.45 b	6.30 ± 0.26 b	23.20 ± 0.34 b
T4	77.86 ± 1.95 b	4.86 ± 0.22 c	29.6 ± 0.6 b	13.87 ± 0.15 c	6.23 ± 0.15 b	22.02 ± 0.37 c
T5	69.72 ± 1.28 c	4.52 ± 0.15 c	27.0 ± 0.7 c	12.83 ± 0.85 c	5.27 ± 0.15 c	19.96 ± 0.80 d

Note: Different letters in the same column indicate significant differences among treatments ($p < 0.05$, $n = 3$).

3.4. The Activities of Carbon Metabolism Enzyme in Leaves at Different Stages After Flowers Withering

From the flowering stage to 60 days after anthesis, the SS activity in the five treatments showed a trend of first increasing and then decreasing (Figure 3), reaching maximum activity at 45 days after anthesis. At this time, SS activity increased by 52.6%, 36.5%, 41.7%, 41.1%, and 40.2%, respectively, compared to the flowering stage of the T1–T5 treatments. From 45 to 60 days after anthesis, the activity of SS decreased. The activity of SS at 60 days after anthesis was roughly the same as that at 30 days after anthesis. The SS activity in T1 was higher than in the other four treatments during the five periods from the flowering stage to 60 days after anthesis. In particular, at 45 days after anthesis, the SS activity in T1 was significantly higher than in T5 by 17.4%. The activities of SPS and SS showed different trends. Across the five substrate treatments, the activity of SPS rose from the beginning of flowering to 60 days after anthesis, reaching its maximum at this time. At this stage, the SPS activity across the T1-T5 treatments increased by 96.7%, 111.0%, 107.0%, 83.1%, and 108.3% compared to the flowering period, respectively. At 15–45 days after flowering, there were no significant differences in the activity of SPS between T2, T3, and T4.

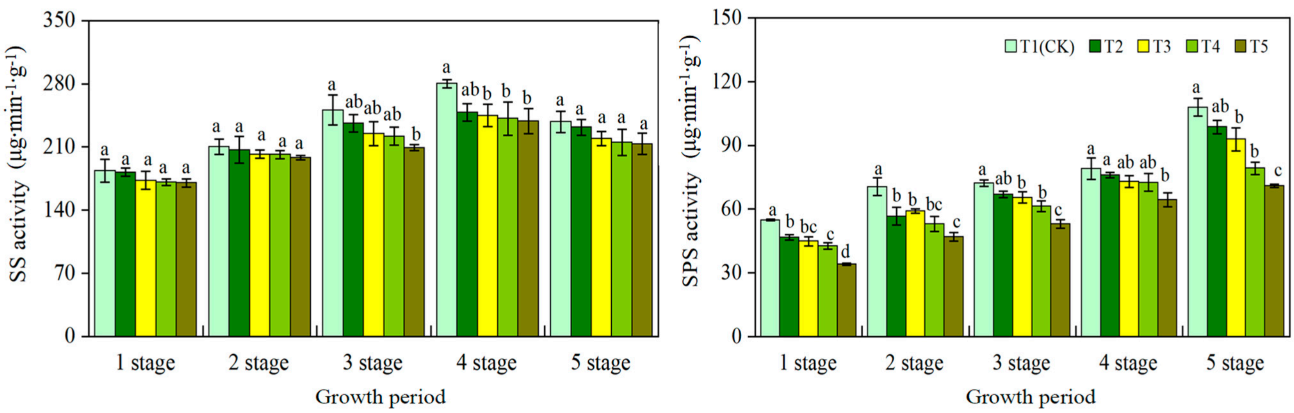

Figure 3. Changes in the activities of sucrose synthetase (SS) and sucrose phosphate synthetase (SPS) of 'Siberia' lily leaves based on peat and SCB in different proportions. (Stage 1 refers to the flowering stage; stages 2, 3, 4, and 5 refer to the 15th, 30th, 45th, and 60th days after the flowering stage, respectively.) Different letters on the bar chart indicate significant differences among treatments ($p < 0.05$, $n = 3$).

3.5. Comparison of Bulb Quality in Different Substrates

Bulb circumference is a visual indicator used to evaluate lily bulb size. It can be seen that the circumference of the bulbs in T1–T4 all exceeded 20 cm, with no significant variance among the different treatments (Table 5). Moreover, the circumferences in T1–T3 surpassed 24 cm; only those in T5 fell below 20 cm. Fresh weight and circumference did not show the same patterns. The fresh weight of the T1 bulbs was more than 170 g, and the difference between T1 and T3 was not significant. The fresh weights of the T4 and T5 bulbs were

36.6% and 67.2% less than those of T1. There was no significant difference in the height of the bulbs among the five treatments. T1 bulbs measured 6.5 cm, while the bulbs from the T2–T5 treatments were over 7 cm in height. The starch content decreased sequentially between T1 and T5, with the contents of T3 and T4 being relatively close. The variations observed in circumference, fresh weight, and starch content were similar across the five substrate treatments, yet there was no significant change in bulb height.

Table 5. The quality indicators of bulbs in 5 substrates based on peat and SCB in different proportions.

Treatment	Bulb Circumference (cm)	Bulb Fresh Weight (g)	Bulb Height (cm)	Starch Content ($mg \cdot g^{-1}$)
T1(CK)	24.33 ± 0.90 a	176.37 ± 9.89 a	6.50 ± 0.30 a	145.72 ± 0.92 a
T2	24.03 ± 0.45 a	162.07 ± 6.77 a	7.13 ± 0.74 a	129.26 ± 5.02 b
T3	24.43 ± 0.64 a	163.60 ± 4.98 a	7.17 ± 0.45 a	118.06 ± 6.00 bc
T4	21.50 ± 0.70 ab	129.07 ± 7.28 b	7.17 ± 0.76 a	115.95 ± 6.79 c
T5	19.83 ± 2.15 b	105.50 ± 3.64 c	7.13 ± 0.47 a	102.97 ± 0.42 d

Note: Different letters in the same column indicate significant differences among treatments ($p < 0.05$, $n = 3$).

3.6. Correlation Analysis

The results show that the contents of chlorophyll a and b and total chlorophyll in the leaves of ‘Siberian’ lilies had the same correlation performance with the physicochemical properties of the substrates. Except for the significantly negative correlation with the pH, the organic matter and reducing sugar content of the substrates, the contents of chlorophyll a and b and total chlorophyll also had significant positive correlation with bulk density, total porosity, water-holding porosity, ventilation porosity, EC value, hydrolyzed N, available P, and exchange Ca content of substrates ($p < 0.05$). The plant height, stem diameter, leaf number, leaf length and width, flower diameter of cut flowers, fresh weight, starch content, and the activities of SS and SPS of the bulbs were also significantly negative correlated with pH, organic matter, and reducing sugar content of the substrate, and significantly positively correlated with bulk density, total porosity, water-holding porosity, and hydrolyzed N content of the substrate ($p < 0.05$) (Table 6). The bulb circumference was significantly positively correlated with the water-holding porosity of the substrates, while the correlation between the bulb height and the physicochemical properties of the substrates was completely opposite to the other quality indicators of bulbs ($p < 0.05$) (Figure 4).

Table 6. The correlation between different quality indicators of the cut flowers and bulbs of 'Siberia' lily with the physicochemical properties of substrates based on peat and SCB in different proportions.

	Chlorophyll a	Chlorophyll b	Total Chlorophyll	Plant Height	Stem Diameter	Leaf Number	Leaf Length	Leaf Width	Flower Diameter	Fresh Weight of Bulb	Bulb Circumference	Bulb Height	Sucrose Synthase	Sucrose Phosphate Synthase	Starch
Bulk density	0.998 *	0.984 *	0.991 *	0.899 *	0.962 *	0.965 *	0.973 *	0.976 *	0.962 *	0.924 *	0.845	−0.771	0.980 *	0.988 *	0.993 *
Total porosity	0.982 *	0.954 *	0.976 *	0.935 *	0.956 *	0.971 *	0.949 *	0.989 *	0.986 *	0.946 *	0.877	−0.737	0.948 *	0.998 *	0.979 *
Aaeration porosity	0.975 *	0.987 *	0.981 *	0.842	0.940 *	0.938 *	0.965 *	0.956 *	0.922 *	0.879 *	0.787	−0.813	0.996 *	0.962 *	0.992 *
Water-holding porosity	0.987 *	0.944 *	0.970 *	0943 *	0.952 *	0.970 *	0.942 *	0.988 *	0.990 *	0.950 *	0.885 *	−0.721	0.936 *	0.998 *	0.971 *
pH	−0.953 *	−0.890 *	−0.936 *	−0.978 *	−0.923 *	−0.988 *	−0.917 *	−0.948 *	−0.978 *	−0.930 *	−0.889 *	0.544	−0.855	−0.956 *	−0.919 *
Electrical conductivity	0.901 *	0.923 *	0.910 *	0.741	0.855	0.846	0.872	0.939 *	0.860	0.805	0.690	−0.929 *	0.978 *	0.922 *	0.962 *
Organic mater	−0.991 *	−0.988 *	−0.994 *	−0.927 *	−0.997 *	−0.956 *	−0.995 *	−0.914 *	−0.961 *	−0.963 *	−0.917 *	0.646	−0.932 *	−0.971 *	−0.943 *
Reducing sugar	−0.982 *	−0.997 *	−0.990 *	−0.879 *	−0.984 *	−0.931 *	−0.990 *	−0.910 *	−0.935 *	−0.935 *	−0.874 *	0.715	−0.957 *	−0.961 *	−0.952 *
Hydrolyzable N	0.980 *	0.951 *	0.974 *	0.924 *	0.942 *	0.976 *	0.946 *	0.994 *	0.978 *	0.924 *	0.848	−0.745	0.955 *	0.992 *	0.987 *
Available P	0.894 *	0.933 *	0.909 *	0.695	0.839	0.842	0.885 *	0.904 *	0.813	0.750	0.627	−0.907 *	0.988 *	0.883 *	0.959 *
Available K	0.847	0.874	0.858	0.674	0.796	0.785	0.812	0.910 *	0.809	0.749	0.624	−0.962 *	0.951 *	0.881 *	0.929 *
Exchangeable Ca	0.914 *	0.931 *	0.922 *	0.772	0.879 *	0.856	0.885 *	0.944 *	0.883 *	0.841	0.735	−0.910 *	0.973 *	0.939 *	0.961 *
Exchangeable Mg	0.805	0.843	0.819	0.606	0.746	0.740	0.773	0.876	0.753	0.684	0.548	−0.982 *	0.936 *	0.835	0.904 *

Note: * indicates significant correlation ($p < 0.05$).

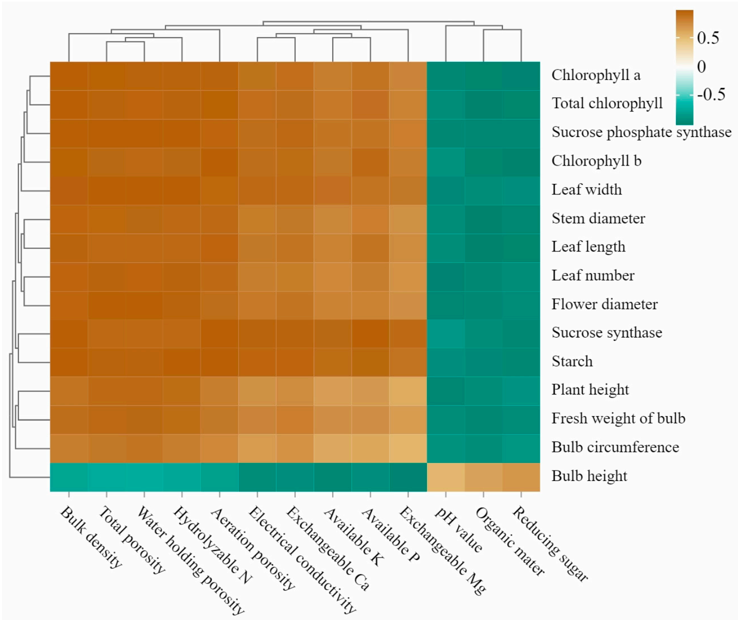

Figure 4. Heatmap of the correlation between the quality indicators of the cut flowers and bulbs of 'Siberia' lily with the physicochemical properties of substrates based on peat and SCB in different proportions.

3.7. Evaluation of Cut Flower and Bulb Quality in Lilies

The results of the principal component analysis show that the cumulative contribution rate of the first two components reached 81.8%, representing most of the information in the original data (Figure 5). In the loading plot, the contribution rate of the first principal component (PC1) was 68.3%, of which the stem diameter load was 0.303, leaf number load was 0.301, flower diameter load was 0.304, and SPS load was 0.306, accounting for the highest proportion. The contribution rate of the second principal component (PC2) was 13.5%, of which the chlorophyll a load was 0.286, chlorophyll b load was 0.635, and total chlorophyll load was 0.663, accounting for the highest proportion. In conclusion, the stem diameter, leaf number, flower diameter, SPS activity, chlorophyll a and b, and total chlorophyll were extracted as the core indexes for evaluating the suitability of cultivated substrate for cut lily flowers. In the score plot, the location features of the samples at T2 and T3 are similar, and they are closer to T1, indicating that the principal component features of the samples at T2 and T3 were similar to those at T1.

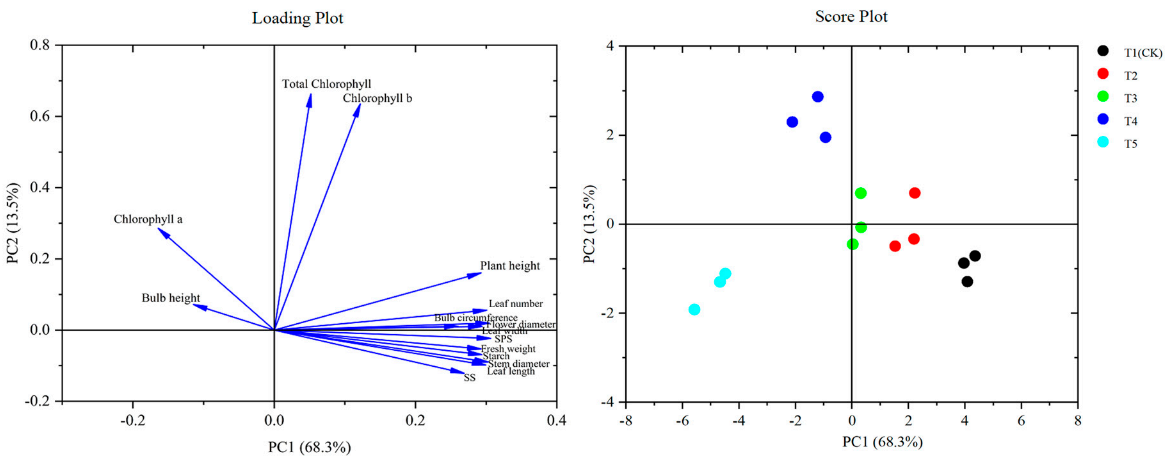

Figure 5. Map of two-dimensional principal component analysis of 15 quality parameters of cut flowers and bulbs (the left one is the loading plot and the right one is the score plot) ($p < 0.05$, $n = 3$).

4. Discussion

SCB is commonly used as a cultivation substrate for fungi [26], but its application in flowers is not widespread. For the soilless cultivation of horticultural crops, the substrate needs to have good air permeability and water-holding capacity, as well as a stable composition and structure. It also should not affect the absorption of fertilizer components by plants [27]. In this study, the physical characteristics of the mixed-media substrate, including bulk density, aeration porosity, water-holding porosity, and total porosity, decreased with the increase in SCB addition. In particular, the bulk density of the mixture with 75% SCB was 21.1% lower than that of T1. The suitable range of bulk density for horticultural crop growth media is less than 0.4 g·cm^3 [28]. The bulk density of the mixed media in this study was 0.15–0.17 g/cm^3, which is obviously in line with this range. In general, the indicators of aeration porosity, water-holding porosity, and total porosity can reflect the cultivation suitability of soilless substrate [29], 54–96% total porosity, 15–30% aeration porosity, and 36–77% water-holding porosity are suitable for plant growth [30]. In this study, the total porosity (73.41–80.56%) and water-holding porosity (69.57–75.33%) of the mixed substrate were within the recommended range, but the aeration porosity (3.85–5.23%) was significantly lower than the recommended range, although this did not have a serious impact on the growth of the cut flowers and bulbs. These results indicate that the range of aeration porosity requirements for lily, as a bulbous plant, is different from that of conventional perennial plants. For lilies, the suitability of water-holding porosity may have a greater influence on growth.

In terms of chemical properties, the pH value, reducing sugar content, and organic matter content in the mixed media gradually increased with the increase in SCB. The pH change rule of SCB found in this paper was different from that found in related research on Osteospermum; the pH value of the cultivation substrate of Osteospermum decreased with the increase in SCB [21], which may be related to the storage time of SCB. The SCB in the Osteospermum test was old SCB that had been stored for more than 2 years, while the SCB used in this experiment was a new product.

The strength of plant growth can be reflected by morphological indicators. These can be used to intuitively determine the differences in the effects of different cultivation substrates on plant growth, and thus judge the quality of the cultivation substrate [31]. In this study, replacing peat with SCB had a great impact on the physical and chemical properties of the substrate. This led to differences in the quality characteristics of cut flowers and bulbs, including differences in chlorophyll content, the activities of carbon-metabolizing enzymes, and morphological characteristics.

At different growth stages, the contents of total chlorophyll of lily plants with five substrate treatments were found to be in the following order: T1 > T2 > T3 > T4 > T5. The photosynthesis of plants is not only controlled by environmental factors, such as temperature and light intensity [32], but also by chlorophyll content, which affects the accumulation of plant photosynthetic products through light reaction in the first stage of photosynthesis. In addition, since chlorophyll a accounts for the highest proportion of total chlorophyll, changes in chlorophyll a content can also impact the strength of photosynthesis to a certain extent [33]. The correlation analysis in this article showed that the chlorophyll content in the leaves of the studied plants was positively correlated with the hydrolytic N content in the substrate; a higher chlorophyll content was found in plants grown in substrates with a higher hydrolyzed N content. Since the hydrolyzed N content in SCB is much lower than in peat, the chlorophyll content in T2, with a lower proportion of SCB, was the closest to that in T1. These results are similar to the conclusion that the chlorophyll content of rice increases with increases in N application [34,35].

SPS and SS are key enzymes in plant sugar metabolism pathways, and multiple isomers of the two enzymes may play a role in the different growth stages of plants [36]. In this study, the activities of SPS and SS were different at different periods from florescence to 60 days after anthesis, confirming the results of previous studies. The activities of the two carbon-metabolizing enzymes were the highest in the substrate supplemented with

25% SCB, showing significant positive correlations with exchangeable Ca and available P in the substrate. Studies on the localization of SPS and SS have demonstrated that both enzymes control the diversity of other enzyme regulatory mechanisms through Ca-dependent reversible protein phosphorylation [37,38], suggesting that increasing the content of exchangeable Ca and available P in the cultivation substrate could promote the activities of SPS and SS in lily. In addition, the starch content of the bulbs in the five substrates showed change patterns in line with the activity of SPS and SS. These results are consistent with the conclusion that the activities of SPS and SS in soybean leaves positively affect starch accumulation in soybean seeds, and that starch content increases with increases in biochar feed [39].

For cut lily flowers, the morphological indicators that can be used as quality evaluation criteria include plant height, stem diameter, bud number, and flower diameter [40]. The important quality grading indexes of commercial lily bulbs include circumference, health status, the fresh weight of bulbs, and starch content [41]. In this study, the T1 substrate had the characteristics of loose porosity, good ventilation, strong water-holding capacity, and a high content of fertilizer elements, which could provide a good physical environment for the growth of the aboveground and underground parts of cut lily flowers. Therefore, plants in the T1 group not only had the highest chlorophyll content in the growth process, but also the best plant height, stem diameter, leaf number, flower diameter, bulb circumference, and fresh weight of the five treatments. Compared to peat, the physical and chemical properties of SCB are obviously characterized by a poor air permeability and low effective nutrient content. Although SCB had 14.1% more organic matter than peat, this organic matter was mainly composed of cellulose and hemicellulose [13], which cannot be directly absorbed by roots. Matter of this kind needs to be fermented and decomposed by microorganisms into soluble compounds before it can be utilized by plants [42]. Although the reducing sugar in the substrate is soluble in water, it mostly serves as a living carbon source of microorganisms in the soil or substrate, which can improve bacterial community abundance and enhance root vitality [43,44]. This does not directly affect the morphological development of plants. Therefore, although the reducing sugar content of SCB was 35.5% higher than that of peat, this did not affect the growth of the lilies. In addition, SCB had a low content of effective fertilizer components, being deficient in N, P, and Ca in particular. This severe deficiency of Ca could have a serious impact on flower development, leading to the abnormal growth of flowers [45], while shortages in N and P would shorten lily plants and reduce leaf area and flower diameter [46].

In this study, the T2, T3, and T4 treatments improved the undesirable physical and chemical properties of SCB by combining it with peat. The morphological indexes of the cut flowers produced in the T2 and T3 substrates were close to those in the T1 substrate, and the plant height and flower diameter of plants grown in the T2 substrate were only 1.3 cm lower than those of the T1 substrate. Even the various quality indicators of cut flowers produced in the T4 substrate exceeded those produced in the T5 substrate. Cucumber seedlings produced with a mixture of SCB–vermiculite in a volume ratio of 1:1 showed significantly better plant height and stem diameter than those produced with a control substrate mainly composed of peat, perlite, and vermiculite. Thus, the feasibility of using SCB as a substrate for the soilless cultivation of horticultural crops was verified, making SCB a candidate substrate component for the successful cultivation of cucumber seedlings [47]. For cucurbit seedlings produced in greenhouses, SCB biochar serves as a supplementary substrate that can be mixed with other commercial substrates at a volume ratio of 25% to 50% to obtain high-quality seedlings [19]. The quality performance of cut lily flowers and bulbs in this study showed that mixtures of bagasse and peat at a ratio of less than 50% (v/v) could be used for the soilless cultivation of lilies as an alternative substrate for cut flower and bulb production. The results confirm that SCB is not suitable for use as a single substrate.

5. Conclusions

After replacing peat with SCB in a reasonable proportion, the physical and chemical properties of the mixed substrate, such as bulk density, aeration porosity, water-holding porosity, pH value, EC value, and exchangeable Ca content, were improved, basically meeting the requirements for the soilless cultivation of lilies. According to the growth effects of cut lily flowers, the substrate treatments with SCB contents of 25% and 50% were significantly superior to the other treatments in terms of plant morphological and physiological indicators, and the quality of cut flowers and bulbs produced was closer to that using peat. Therefore, it is feasible to use SCB as an additive component in soilless cultivation substrate for lilies. The use of SCB not only reduces peat consumption, but is also beneficial for the ecological environment and has good application prospects.

Author Contributions: Conceptualization, G.C., W.D. and J.W.; methodology, G.C. and J.W.; formal analysis, G.C., W.D. and Q.D.; investigation, G.C. and W.D.; resources, G.C. and W.D.; data curation, G.C., X.L. and L.M.; writing—original draft preparation, G.C. and W.D.; writing—review and editing, G.C. and J.W. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by grants from the National Key Research and Development Program (2023YFD23009031, 2023YFD23009032) of Ministry of Science and Technology of the People's Republic of China and the Seed Industry Joint Laboratory Project (202205AR070001-14) of Yunnan Province Science and Technology Department.

Data Availability Statement: Data is contained within the article.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Barrett, G.; Alexander, P.; Robinson, J.; Bragg, N. Achieving environmentally sustainable growing media for soillessplant cultivation systems—A review. *Sci. Hortic.* **2016**, *212*, 220–234. [CrossRef]
2. Nejad, A.; Ismaili, A. Changes in growth, essential oil yield and composition of geranium (*Pelargonium graveolens* L.) as affected by growing media. *J. Sci. Food Agric.* **2014**, *94*, 905–910. [CrossRef] [PubMed]
3. Kromwijk, J.; Os, E. Advances in soilless culture of ornamentals. In *Advances in Horticultural Soilless Culture*; Burleigh Dodds Science Publishing: Cambridge, UK, 2021; pp. 401–416. [CrossRef]
4. Li, J.; Xu, Y. Effects of continuous cropping years of lily on soil physicochemical properties and biological characteristics. *Chin. J. Soil Sci.* **2019**, *50*, 1171–1177. [CrossRef]
5. Sun, J.; Li, Q.; Yue, D.; Gao, H.; Kang, Y.; Tian, J.; Li, J.; Guo, S. Research status and application prospects of soilless culture technology in the world. *J. Nanjing Agric. Univ.* **2022**, *45*, 898–915. [CrossRef]
6. Prisa, D.; Burchi, G.; Antonetti, M.; Teani, A. Use of organic or inorganic substrates for reducing the use of peat and improving the quality of bulbs and inflorescences in asiatic lily. *Acta Hortic.* **2011**, *900*, 143–148. [CrossRef]
7. Bragg, N.; Brough, W. The development of responsibly sourced growing media components and mixes. *Acta Hortic.* **2014**, *1055*, 141–144. [CrossRef]
8. Banitalebi, G.; Mosaddeghi, M.; Shariatmadari, H. Feasibility of agricultural residues and their biochars for plant growing media: Physical and hydraulic properties. *Waste Manag.* **2019**, *87*, 577–589. [CrossRef]
9. Ma, H.; Liu, Z.; Duan, Z.; Pan, Z.; Zhang, C.; Zhao, S. The effect of vermicompost replacing peat on the physical and chemical properties of the substrate and the growthof two flowers of green radish and Chlorophytum. *Soil Fertil. Sci. China* **2021**, *5*, 112–118. [CrossRef]
10. Feng, B.; Ren, S.; Huang, L.; Liu, C.; Dong, L. Research on substrates as peat substitute for cut flower production of oriental lily. *Acta Hortic. Sin.* **2010**, *37*, 1637–1644. [CrossRef]
11. Heidari, S.; Mortazavi, S.; Reezi, S.; Nikbakht, A. Composted palm waste as an alternative of coco peat in growing media: Effects on growth and nutritional status of lily cut flower (*Lilium* spp.). *J. Hortic. Postharvest Res.* **2021**, *4*, 49–66. [CrossRef]
12. Al-Ajlouni, M.; Ayad, J.; Othman, Y. Particle size of volcanic tuff improves shoot growth and flower quality of asiatic hybrid lily using soilless culture. *Horttechnology* **2017**, *27*, 223–227. [CrossRef]
13. Alokika; Anu; Kumar, A.; Kumar, V.; Singh, B. Cellulosic and hemicellulosic fractions of sugarcane bagasse: Potential, challenges and future perspective. *Int. J. Biol. Macromol.* **2021**, *169*, 564–582. [CrossRef] [PubMed]
14. Guilherme, A.; Dantas, P.; Padilha, C.; Dos Santos, E.; De Macedo, G. Ethanol production from sugarcane bagasse: Use of different fermentation strategies to enhance an environmental-friendly process. *J. Environ. Manag.* **2019**, *234*, 44–51. [CrossRef] [PubMed]
15. Vieira, C.; Codogno, M.; Filho, F.; Filho, R.; Mariano, A. Sugarcane bagasse hydrolysates as feedstock to produce the isopropanol-butanol-ethanol fuel mixture: Effect of lactic acid derived from microbial contamination on Clostridium beijerinckii DSM 6423. *Bioresour. Technol.* **2021**, *319*, 124140. [CrossRef]

16. Antunes, F.; Thome, L.; Santos, J.; Ingle, A.; Costa, C.; Dos Anjos, V.; Bell, M.; Rosa, C.; Da Silva, S. Multi-scale study of the integrated use of the carbohydrate fractions of sugarcane bagasse for ethanol and xylitol production. *Renew. Energy* **2021**, *163*, 1343–1355. [CrossRef]
17. Salomão, G.; Agnezi, J.; Bastos Paulino, L.; Hencker, L.; Shimosakai de Lira, T.; Tardioli, P.; Pinotti, L. Production of cellulases by solid state fermentation using natural and pretreated sugarcane bagasse with different fungi. *Biocatal. Agric. Biotechnol.* **2019**, *17*, 1–6. [CrossRef]
18. Pandey, A.; Soccol, C.; Nigam, P.; Soccol, V. Biotechnological potential of agro-industrial residues. I: Sugarcane bagasse. *Bioresour. Technol.* **2000**, *74*, 69–80. [CrossRef]
19. Webber, C., III; White, P., Jr.; Spaunhorst, D.; Lima, I.; Petrie, E. Sugarcane biochar as an amendment for greenhouse growing media for the production of cucurbit seedlings. *J. Agric. Sci.* **2018**, *10*, 104–115. [CrossRef]
20. Orta-Guzmán, V.; Lois-Correa, J.; Domínguez-Crespo, M.; Pineda-Pineda, J.; Torres-Huerta, A.; Rodríguez-Salazar, A.; Licona-Aguilar, Á. Evaluation of sugarcane agroindustrial wastes as substrate in soilless cultivation of tomato (*S. lycopersicum* Linnaeus): Effect of substrate composition on yield production. *Agronomy* **2021**, *11*, 206. [CrossRef]
21. Thiessen, M.; Fields, J.; Abdi, D. Sugarcane bagasse is an effective soilless substrate amendment in Quick-turn *Osteospermum* production. *Hortscience* **2023**, *58*, 1170–1177. [CrossRef]
22. López-Fernández, M.; Moyano, L.; Correa, M.; Vasile, F.; Burrieza, H.; Maldonado, S. Deterioration of willow seeds during storage. *Sci. Rep.* **2018**, *8*, 17207. [CrossRef] [PubMed]
23. Dong, Y.; Liu, B.; Zhang, X.; Liu, X.; Ai, X.; Li, Q. Responses of non-structural carbohydrate metabolism of cucumber seedlings to drought stress and doubled CO_2 concentration. *Chin. J. Appl. Ecol.* **2015**, *26*, 53–60. [CrossRef]
24. Brunt, K.; Sanders, P.; Rozema, T. The enzymatic determination of starch in food, feed and raw materials of the starch industry. *Starch* **1998**, *50*, 413–419. [CrossRef]
25. Sun, X.; Xu, Y.; Ma, L.; Zhou, H. A review of acclimation of photosynthetic pigment composition in plant leaves to shade environment. *Chin. J. Plant Ecol.* **2010**, *34*, 989–999. [CrossRef]
26. Arushdeep, S.; Umar, F. Sugarcane Bagasse: A Potential Medium for Fungal Cultures. *Chin. J. Biol.* **2014**, *2014*, 840505. [CrossRef]
27. Wallach, R. Physical characteristics of soilless media. In *Soilless Culture: Theory and Practice*; Raviv, M., Lieth, J., Bar-Tal, A., Eds.; Elsevier BV: Oxford, UK, 2019; pp. 33–148. [CrossRef]
28. Abad, M.; Noguera, P.; Burés, S. National inventory of organic wastes for use as growing media for ornamental potted plant production: Cause study in Spain. *Bioresour. Technol.* **2001**, *77*, 197–200. [CrossRef]
29. Caron, J.; Price, J.; Rochefort, L. Physical properties of organic soil: Adapting mineral soil concepts to horticultural growing media and histosol characterization. *Vadose Zone J.* **2015**, *14*, 1–14. [CrossRef]
30. Tian, Y.; Sun, X.; Li, S.; Wang, H.; Wang, L.; Cao, J.; Zhang, L. Biochar made from green waste as peat substitute in growth media for *Calathea rotundifola* cv. *Fasciata*. *Sci. Hortic.* **2012**, *143*, 15–18. [CrossRef]
31. Ai, J.; Hou, L.; Shao, G.; Li, Z.; Meng, C.; Lu, L.; Sun, Q. Physicochemical property of different forestry waste formula substrates and comprehensive evaluation of their effects on growth of Betula alnoides seedlings. *J. Plant Resour. Environ.* **2018**, *27*, 66–76. [CrossRef]
32. Kvíderová, J.; Elster, J.; Komárek, J. Ecophysiology of cyanobacteria in the polar regions. In *Cyanobacteria*; Academic Press: Cambridge, MA, USA, 2019; pp. 277–302. [CrossRef]
33. Bjorn, L.; Papageorgiou, G.; Blankenship, R.; Govindjee. A viewpoint: Why chlorophyll *a*? *Photosynth. Res.* **2009**, *99*, 85–98. [CrossRef]
34. Ata-Ul-Karim, S.; Cao, Q.; Zhu, Y.; Tang, L.; Rehmani, M.; Cao, W. Non-destructive Assessment of Plant Nitrogen Parameters Using Leaf Chlorophyll Measurements in Rice. *Front. Plant Sci.* **2016**, *7*, 1829. [CrossRef] [PubMed]
35. Yang, H.; Li, J.; Yang, J.; Wang, H.; Zou, J.; He, J.; Hui, D. Effects of nitrogen application rate and leaf age on the distribution pattern of leaf SPAD readings in the rice canopy. *PLoS ONE* **2014**, *9*, e88421. [CrossRef] [PubMed]
36. Bilska-Kos, A.; Mytych, J.; Suski, S.; Magoń, J.; Ochodzki, P.; Zebrowski, J. Sucrose phosphate synthase (SPS), sucrose synthase (SUS) and their products in the leaves of *Miscanthus* × *giganteus* and *Zea mays* at low temperature. *Planta* **2020**, *252*, 23. [CrossRef] [PubMed]
37. Fedosejevs, E.; Ying, S.; Park, J.; Anderson, E.; Mullen, R.; She, Y.; Plaxton, W. Biochemical and molecular characterization of RcSUS1, a cytosolic sucrose synthase phosphorylated in vivo at serine 11 in developing castor oil seeds. *J. Biol. Chem.* **2014**, *289*, 33412–33424. [CrossRef] [PubMed]
38. Almadanim, M.; Alexandre, B.; Rosa, M.; Sapeta, H.; Leitao, A.; Ramalho, J.; Lam, T.; Negrao, S.; Abreu, I.; Oliveira, M. Rice calcium-dependent protein kinase OsCPK17 targets plasma membrane intrinsic protein and sucrose-phosphate synthase and is required for a proper cold stress response. *Plant Cell Environ.* **2017**, *40*, 1197–1213. [CrossRef]
39. Zhu, Q.; Kong, L.; Shan, Y.; Yao, X.; Zhang, H.; Xie, F.; Ao, X. Effect of biochar on grain yield and leaf photosynthetic physiology of soybean cultivars with different phosphorus efficiencies. *J. Integr. Agric.* **2019**, *18*, 2242–2254. [CrossRef]
40. Wei, G.; Fang, Z.; Li, F. Effects of different nitrogen fertilizers and deficit irrigation on quality of lily (*Lilium* spp.) cut-flower. *J. Plant Nutr. Fertil.* **2017**, *23*, 244–253. [CrossRef]
41. Ouyang, T.; Cai, X.; Fang, S.; Guo, W.; Wei, C.; Lin, Z.; Lin, J. Propagation and breeding technologies of bulbs of oriental lily in mountainous region. *Acta Agric. Boreali-Sin.* **2008**, *17*, 274–277. [CrossRef]

42. Mai, Y.; Bu, R.; Han, S.; Lei, Z.; Li, M.; Wang, H.; Cheng, W.; Tang, S.; Wu, J.; Zhu, L. Effects of adding different exogenous nitrogen on rice straw decomposition and nutrient release. *Trans. Chin. Soc. Agric. Eng.* **2021**, *37*, 210–219. [CrossRef]
43. Qi, B.; Zhang, K.; Qin, S.; Lyu, D.; He, J. Glucose addition promotes C fixation and bacteria diversity in C-poor soils, improves root morphology, and enhances key N metabolism in apple roots. *PLoS ONE* **2022**, *17*, e0262691. [CrossRef]
44. Lang, D.; Zhu, Z.; Qin, S.; Lyu, D. Root architecture and nitrogen metabolism in roots of apple rootstock respond to exogenous glucose supply in low carbon soil. *Plant Soil Environ.* **2018**, *64*, 240–246. [CrossRef]
45. Hepler, P. Calcium: A Central Regulator of Plant Growth and Development. *Plant Cell* **2005**, *17*, 2142–2155. [CrossRef]
46. Cui, G.; Du, W.; Wu, X.; Duan, Q.; Ma, L.; Jia, W.; Li, S.; Wang, X. Effects of fertilization levels of nitrogen, phosphorus and potassium on the quality of cut flowers and bulb-lets of lily. *Chin. Agric. Sci. Bull.* **2021**, *37*, 65–70. [CrossRef]
47. Zhang, S.; Yu, H.; Jiang, W. Seedling effects of corncob and bagasse composting substrates in cucumber. *Trans. Chin. Soc. Agric. Eng.* **2015**, *31*, 236–242. [CrossRef]