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Effects of the LED Source on Growth and Nutritional Quality of Chinese Chive in Different Cutting Stages and their Comprehensive Evaluation

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Abstract: *In this experiment, we used four kinds of LED lights with different red and blue light ratio(R/B=3:1; 4:1; 5:1; 7:1), and the white light was used as the control. The method of principal component analysis was used to evaluate the effects of different ratios of red light to blue light (R/B) on the growth and nutrient quality of Chinese chive.The results showed that thevalues, including plant height, stem diameter, leaf width, dry weight, soluble protein content, soluble sugar content, crude fiber content and yieldof Chinese chive, were significantly higher than those of other treatments at the treatment using 7:1 of R/B;While the contents of VC and allicin were significantly higher than those of other treatments. The plant height, stem diameter, leaf width, chlorophyll content and yield of Chinese chive were increasing, while the content of VC was the opposite. The results of principal component analysis showed that R/B was 7:1 in the total score of 1.44, 2.17, 1.35, 2.00, respectively, which were significantly higher than those of other treatments. The sequence of the average score of different treatments was RB4> RB2> RB3> RB1> CK. Therefore, It is an important decision that choosing 7:1 of R/B to improve the growth and nutritional quality of Chinese chive in northern China.*

Keywords: *LED, Growth of Chinese chive, Nutritional quality, Light quality, Principal component analysis.*

1. Introduction

Light, the only energy source in the photosynthesis, has a particularly important role in the growth of plants which affects almost all crop development stages [1-3]. In the process of growth and development, plants will rely on sunlight. The supplemental light based on the artificial light sources is a common method used in factory production and tissue culture of vegetables, flowers and other cash crops,.In late autumn, winter and spring sunshine time is short, especially cloudy, fog, rain and snow days.As a result, the growth and development of crops are hampered.Therefore, it is an effective way to promote plant growth to adopt directly the artificial light in the greenhouse or high greenhouse[4-5].

In recent years, the research and application of biological characteristics and light source characteristics have proved that the elements of light environment in plants are composed of PPFD (effective radiation of light synthesis), light cycle and light distribution. And the reasonable design of light source promotes the growth and development of plants.[6-7].So far light sources used for plants lighting, mainly include: incandescent lamps that rely on high temperature tungsten filament to launch continuous spectrum,fluorescent lamps that rely on mercury ultraviolet (253.7nm) to light; new semiconductor light source LED lights[1]. LED (light emitting diode) has been well applied in the cultivation of vegetables, because of which has small heat, small single tube light radiation, the use of light band structure for lighting, moisture and low power consumption, the advantages of comparable optical properties [8-9].

Chinese chive (*Allium tuberosum* Rottl. ex Spreng）is one of the most traditional Chinese characteristic vegetables, which has more than 3,000 years of cultivation history so far [10]. Leeks are in people's good graces because of its unique flavor, fresh quality and variety diversity. Leeks are cultivated all the world, especially in north of China. High latitudes and lack of light in the northern China are the main factors restricting the production of leek in winter. The influence of LED light source on leek and photosynthetic characteristics has been discussed[11,12]，but mainly focused on the

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effect of monochromatic light on the growth and development of single chives and the lack of comprehensive evaluation of each treatment. In this experiment, we use different proportion of red and blue light of LED light quality of the four chives for the cultivation of chives, to explore the effects of different light quality on growth and nutritional quality and use the principal component analysis to comprehensively evaluate , in order to find the optimum ratio of red and blue light was suitable for the growth of Chinese chives in the high latitudes of northern China, and lay a theoretical foundation for improving the quality and yield of Chinese chives.

2. Materials and Methods

2.1 Experiment Material

The experiment was carried out in the Research Office of Modern Horticultural Facilities of Northeast Agricultural University in China in 2016. The selection of "purple root red" leek cultivation was chosen. In December 2016, leeks took the field of routine management which were seeded in the solar greenhouse. In February 2017, we pruned the roots of leeks in the greenhouse (remained 5cm), transplanted to the nursery tray (53cm*25.5cm*6cm), 4 rows per dish, 8 clusters per row, 5 strains per bundle, whose substrate was peat, vermiculite and organic fertilizer. After 30 days of transplanting, the first crop of leek was cut and the nursery tray was transferred to artificial weather and light culture incubator, and cultured under different wavelengths. We controlled the temperature in the day is (23±1) ℃, the temperature at night is (11±1) ℃. We shined a lighton them for 12 hours a day and did a fine management of the growth process. 30 days later, we harvested fresh leeks to measure the indexes.

2.2 Light Quality Selection and Processing Conditions

Test set up five light source processing, respectively, red and blue combination of LED light （according to the number of red and blue lights=3:1,4:1,5:1 and 7:1,the following are represented by RB_1,RB_2,RB_3,RB_4），with white light (CK) of the ordinary light as a control, the above light quality by the Shenzhen Yuhao Optoelectronics Co., Ltd. to provide. The spectra of the different treatments were determined by the American UnispecTM spectroscopy system, and the light emission spectra were shown in Fig1. Adjust the distance between the light source and the leek, so that the light intensity is 200μmol m^{-2} s^{-1}. The light culture frame is a steel frame structure. The light source is at the top and its height is adjustable. The inner layer of the culture bed is made of the aluminum reflective film, and the outer layer is made of the black shading material. Each light quality was randomly arranged, each light quality repeated 3 times. As can be seen from Figure 1.

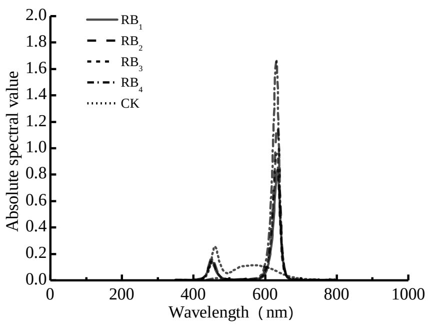

Figure 1: Spectra of different light qualities

2.3 Measure the Project

Experiments were conducted on 4 crops of leek harvested for each treatment. The first crop, the second crop, the third crop and the fourth crop were harvested on February 20, 2017, March 21, April 20 and May 20, respectively. Determination of growth characteristics of leeks: vernier caliper determination of plant height, stem diameter, leaf width, electronic balance of the upper part of the edible part of the fresh and fresh weight. Determination of Nutritional Quality of Leek: Chlorophyll content was determined by Lichtenthaler et al.[13]; The soluble protein was determined by Coomassie brilliant blue G-250 method[14]; The Vc content was determined using 2,6-dichloroindophenol

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titration[15]; The crude fiber content was determined by acid-base digestion method[15];The soluble sugar content was determined by the anthrone method[14]; Allicin was determined by gas chromatography-mass spectrometry; the yield of leek was determined.

2.4 Data analysis Method

Data are expressed as mean ± standard error; all data in the test are used Excel 2010 and Origin 8.5 for finishing analysis and drawing. At the same time, the differences of ANOVA and Duncan were analyzed by SPSS 22.0 software, and the difference was significant ($P < 0.05$).SAS 9.2 software was used for principal component analysis.

3. Results and analysis

3.1 Effects of Different Light Quality on Growth Characteristics of Chinese Chives

The upper part of the leek is the main part of the edible, leeks of the growth indicators can be intuitive to reflect the differences in growth [16]. The effects of different treatments on the growth characteristics of leeks were analyzed according to the different harvests. The results are shown in Tables 1, 2, 3 and 4. According to the results of Table 1, it was concluded that the plant height of different leeks showed a rising trend, and there were significant differences among the treatments. The highest rate of RB_4 was the highest, and CK was the lowest, RB_4 treatment was higher than that of control 18.72%, 18.73%, 18.25% and 17.00% respectively, which indicated that the ratio of red and blue light had a significant effect on the plant height of leek, and the higher proportion of red and blue light, the more obvious the effect on plant height growth..

According to the results of Table 2, it was concluded that the stem diameter of different leeks showed a tendency to become thicker, and there were significant differences among the treatments. The highest rate of RB_4 was the highest and CK was the lowest. In the first crop, the second crop and the third crop, the treatments were mainly RB_4> RB_3> RB_2> RB_1> CK. In addition to CK, the stem diameter of RB_1, RB_2, RB_3, R B_4 was increased by 24.50%, 27.20%, 21.11% and 29.56% respectively compared with the first stubble, which indicated that the light quality had a significant effect on the stem.

According to the results of Table 3, RB_2, RB_3 and RB_4 treatments showed a broadening trend in the whole growth cycle, and were significantly higher than the control. Under the treatment of RB_4, the leaf width was the highest in different times, which was 37.99%, 38.74%, 20.10% and 31.75% higher than the control. In the first and the second crop, the differences between RB1 and RB2 were not significant, and differences between RB3 and RB4 were also not significant. The difference between RB_1 and CK was not significant in the third crop, and the difference between treatments have reached a significant level. The results show that a high proportion of red and blue light has a positive effect on leek leaf width.

Dry weight of the upper part of the ground can indirectly reflect the leek nutrient storage and consumption. According to the results of Table 4, it was concluded that the dry and fresh weight in the upper and lower part of the stubble showed a trend of "up-down-liters", indicating that the second and fourth crops were beneficial to the accumulation of nutrient in leek. The results showed that RB_4 or RB_2 was the highest and CK was the lowest, which indicated that the light quality had a significant effect on the dry and fresh weight of leek. The first crop, second stubble, fourth stubble, the stem diameter was leek were RB_4>RB_2>RB_3>RB_1>CK. second stubble, the differences of RB_2 and RB_3 were not significant; the third crop, the differences of RB_1 and RB_3 were not significant; the fourth crop, the differences of RB_2 and RB_4 were not significant.

Table 1: Effect of light qualities on height of Chinese chive. cm

Treatment	The 1rt crop	The 2nd crop	The 3rd crop	The 4th crop
RB_1	29.73±1.00bcBC	30.09±0.67bcBC	30.39±0.44cBC	30.61±0.59cBC
RB_2	31.22±0.59bB	31.47±0.50bB	31.66±0.80bB	32.07±0.68bB
RB_3	30.59±0.48bBC	30.74±1.22bBC	31.08±0.42bcB	31.28±0.52bcB
RB_4	33.8±1.44aA	34.10±0.85aA	34.27±0.57aA	34.35±0.44aA

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CK	28.47±0.57cC	28.72±0.72bB	28.98±0.58dC	29.36±0.61dC

Note: Different lowercase letters in the same column indicate that Duncan's new complex range test differs significantly at 0.05 level; different capital letters represent significant differences at 0.01 level.

Table 2: Effect of light qualities on stem diameter of Chinese chive. mm

Treatment	The 1rt crop	The 2nd crop	The 3rd crop	The 4th crop
RB_1	2.53±0.06bB	2.75±0.05bB	3.13±0.07bB	3.15±0.07cC
RB_2	2.61±0.05bB	2.82±0.03bB	2.84±0.04cC	3.32±0.04bB
RB_3	2.70±0.04aA	3.02±0.10aA	3.05±0.06bB	3.27±0.07bBC
RB_4	2.74±0.03aA	3.10±0.10aA	3.38±0.04aA	3.55±0.03aA
CK	2.15±0.03cC	2.44±0.05cC	2.61±0.05dD	2.75±0.08dD

Table 3: Effect of light qualities on leaf width of Chinese chive. mm

Treatment	The 1rt crop	The 2nd crop	The 3rd crop	The 4th crop
RB_1	3.43±0.05cC	3.50±0.06dD	3.60±0.10dC	3.51±0.10eD
RB_2	3.82±0.07bB	3.96±0.04cC	4.20±0.12cB	4.76±0.09bA
RB_3	4.21±0.05aA	4.39±0.12bB	4.40±0.11bAB	4.46±0.07cB
RB_4	4.25±0.08aA	4.62±0.10aA	4.60±0.10aA	4.98±0.07aA
CK	3.08±0.12dD	3.33±0.07eD	3.83±0.05dC	3.78±0.05Dc

Table 4: Effect of light qualities on value of dry weight to fresh weight of Chinese chive. %

Treatment	The 1rt crop	The 2nd crop	The 3rd crop	The 4th crop
RB_1	9.13±0.14aD	10.68±0.11cB	8.49±0.10bB	9.15±0.18cBC
RB_2	10.02±0.24bB	11.15±0.22bAB	9.06±0.17aA	9.89±0.05aAB
RB_3	9.55±0.15cC	10.78±0.20bcB	8.57±0.14bAB	9.47±0.24bB
RB_4	10.41±0.12aA	11.65±0.31aA	8.99±0.29aAB	10.15±0.18aA
CK	8.94±0.22dD	9.84±0.19dC	7.90±0.22cC	8.84±0.12dC

3.2 Effects of Different Light Quality on Nutritional Quality of Chinese Chives

The green pigment of leek comes from chlorophyll, into the body after the intestinal toxins can be cleared one by one. As can be seen from Figure 2, the chlorophyll content of leek showed a trend of increasing at different times. The results showed that compared with the first crop the contents of RB1, RB2, RB3, RB4 and CK increased by 13.69%, 19.27% 12.41%, 17.50%, and 5.46% respectively. From the second crop, the chlorophyll content of each treatment was significantly higher than CK, indicating that different red / blue ratio of light quality on the leek chlorophyll content has a significant impact. There was no significant difference between RB_2 and RB_3 treatments in the first and the third crops. The difference between RB_1 and RB_3 was not significant in the fourth crop. CK_4, RB_1, RB_2, RB_3 or CK were the lowest, which indicated that the chlorophyll content of leek was not related to the ratio of red light and blue light, and RB_3 treatment had no significant effect on improving the chlorophyll content of leek.

Soluble protein is an important nutrient component of leek. It can be seen from the results in Fig. 1 that the soluble protein content of leek was significantly different in different cropping times. It shows a trend of “Decreased first and then increased”, which showed the highest treatment rate of RB_4 and the lowest treatment of CK, and the treatment was significantly higher than the control. The results showed that the ratio of red and blue light had significant effect on the chlorophyll content of leek. The second crop and the third crop, the treatment of soluble protein decreased, is due to less accumulation of leek nutrients. RB_3 and RB_4 treatment and RB_1 and RB_2 treatment in the first crop when the difference was not significant. The content of soluble protein in each treatment was: RB_4> RB_3> RB_2> RB_1> CK,

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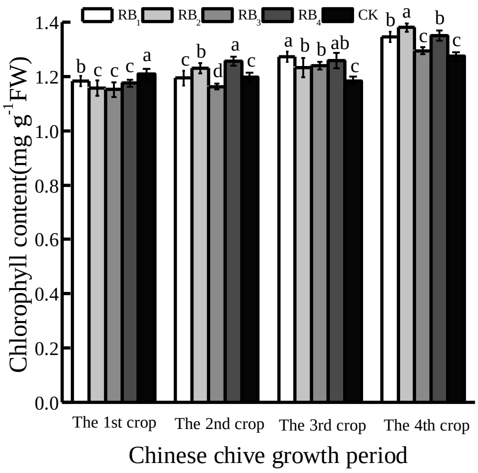
which indicated that the higher ratio of red and blue light could increase the content of soluble protein.



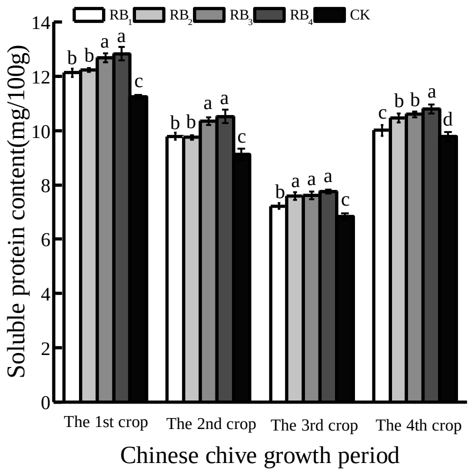


Figure2: Effect of light qualities on Chlorophyll and soluble protein content of Chinese chive

Vitamin C is an antioxidant and is one of the important nutrients in leek, protecting the body from the threat of free radicals. It can be seen from Fig.2 that the content of Vc in the chop was decreased, and RB_1> RB_2> RB_3> RB_4> CK, respectively, which indicated that the ratio of red and blue light had significant effect on the content of Vc in leek. In the second crop, the difference between RB_3 and RB_4 was not significant. The difference between RB_2, RB_3 and RB_4 was not significant at the fourth crop. Compared with CK, RB_1 increased by 27.78%, 18.22%, 19.90% and 7.30%, respectively, which indicated that low proportion of red and blue light could significantly increase the content of Vc in leek.

Crude fiber can promote gastrointestinal motility, can help digestion to a certain extent, crude fiber content is too high will make the taste of chives worse, and will reduce the utilization of other nutrients. It can be seen from Fig. 2 that the crude fiber content of leek was decreased first and then increased, and RB was the highest, CK was the lowest, and the difference between RB_1 and RB_2 was not significant. RB_4>RB_3>RB_2>RB_1>CK ; RB_4>RB_3>CK>RB_1>RB_2 ; RB_4>RB_3>RB_2>RB_1>CK ; RB_4>RB_3>RB_1>RB_2>CK.The results show that, although a high proportion of red and blue light can significantly promote the accumulation of cellulose, but a low proportion of red and blue light culture of leek its crude fiber content is appropriate, more suitable for consumption.

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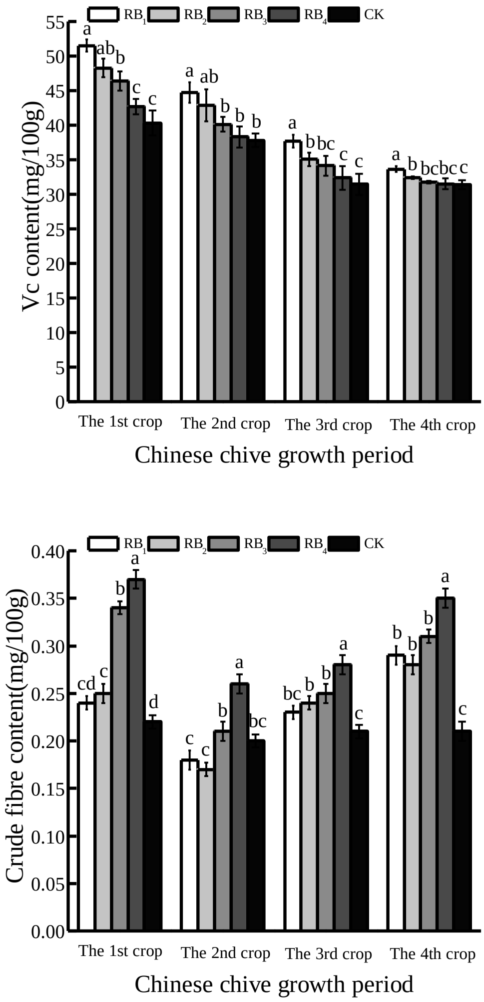
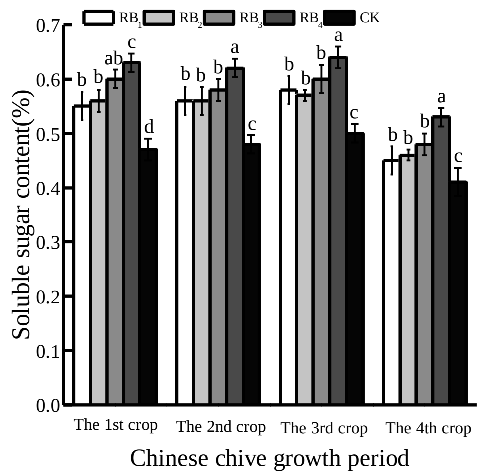


Figure3: Effect of light qualities on Vc and crude fibre content of Chinese chive

Soluble sugar is one of the important components of the plant, but also the main raw material and storage of metabolic substances. It can be seen from Figure 3 that the soluble sugar content of different chilli decreased first and then decreased, and the treatments were significantly higher than those of CK, which showed the highest RB_4 and the lowest CK, indicating that different red / blue ratio Soluble sugar content. In the third crop, the soluble sugar content reached 0.58%, 0.57%, 0.60% and 0.64% respectively. Because of the fast growth rate of sugar in this period, the accumulation of sugar was reduced, so the soluble sugar content in the fourth crop was the highest Sugar content decreased. Except for the first crop, the difference between RB_1, RB_2 and RB_3 was not significant. The soluble sugar content of leek was RB_4> RB_3> RB_2> RB_1> CK, which indicated that the high proportion of red light / blue light was beneficial to the accumulation of soluble sugar in leek.

Chives have a unique flavor because it contains allicin, allicin is a trithioglycol ether compounds, on bacilli, fungi and viruses have an inhibitory effect. The content of allicin in different times was shown in Fig. 3, and the content was "up-down-liters". The results showed that RB_1 was the highest and CK or RB_4 was the lowest, indicating that different red / blue ratio Allicin content. The content of garlicin reached the maximum at the second crop, which was 0.209%, 0.207%, 0.200%, 0.196% and 0.201%, respectively. RB_1 and RB_2 treatment in leeks throughout the growth cycle were not significant differences. Compared with RB_4, RB_1 increased the content of allicin by 5.35%, 3.98%, 7.87% and 4.62%, respectively, which indicated that the low proportion of red light / blue light could promote the increase of allicin content. As can be seen from Figure 4



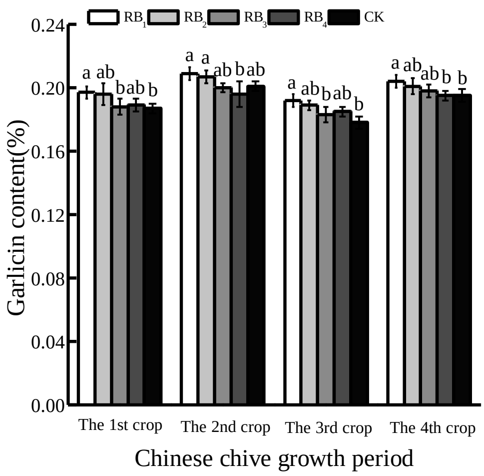


Figure4: Effect of light qualities on soluble sugar and garlicin content of Chinese chive

3.3 Effects of Different Light Quality on Chinese chive Yield

The effect of different light quality on leek yield is shown in Table 5, and the yield of different leeks is increasing, and the treatment yield is the highest in the fourth crop except RB_1. The results showed that RB_4 was the highest and CK was the lowest, indicating that different proportions of red and blue light had a significant effect on the yield of leek. The results showed that the ratio of red and blue was the highest in the second crop, the second crop, the third crop, the fourth crop and the total yield. The total yield of each treatment was RB_4> RB_3> RB_2> RB_1> CK, compared with CK, the total yield of each treatment increased by 14.34%, 39.96%, 42.42% and 64.96% respectively. RB_4 showed significant or significantly higher than any other four treatments during the period of leek growth, indicating that the high proportion of red and blue light had significant effect on the yield of leek.

Table5: Effect of light qualities on yield of Chinese chive. Kg plot^{-1}

Treatment	The 1rt crop	The 2nd crop	The 3rd crop	The 4th crop	Total yield
RB_1	0.57±0.06cB	1.09±0.07bB	2.03±0.14bB	1.89±0.08cC	5.58±0.21cC
RB_2	0.68±0.03bB	1.13±0.04bB	2.35±0.12abA	2.67±0.08bB	6.83±0.21bB
RB_3	0.76±0.04abAB	1.17±0.08bB	2.18±0.07bA	2.84±0.07bB	6.95±0.14bB
RB_4	0.82±0.06aA	1.32±0.04aA	2.43±0.06aA	3.48±0.13aA	8.05±0.16aA
CK	0.47±0.05dB	0.85±0.02cC	1.77±0.03cC	1.79±0.06cC	4.88±0.13dD

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3.4 Principal component analysis

In the test a lot of data variables were often measured, which increases the complexity of the analysis, and may ignore the intrinsic relationship among the data. To solve this problem, the principal component analysis method is usually used. This method simplifies the multi-index into a small number of comprehensive indexes by analyzing and processing large amounts of data, using as few as possible to reflect the original variable information, and finally get a comprehensive comprehensive evaluation of the results of the study [17].

According to the previous results, the first crop as an example, the leek 11 growth and nutritional quality indicators of principal component analysis, the results shown in Table 6. In this experiment, we select the eigenvalues λ> 1 and the cumulative variance contribution rate> 85% to determine the optimal principal component number. It can be seen from Table 6 that the contribution of the first two principal components PC_1 and PC_2 to the explanatory variables is the largest, and the cumulative variance contribution rate is 91.625%, which integrates most of the information of leek growth and nutrient quality.

Table 6: Total variance explained of PCA

The number of principal components	Eigenvalues	Cumulative variance contribution rate（%）
1	7.093	64.486
2	2.985	91.625
3	0.633	97.384
4	0.288	100

When the load factor after the rotation of the load matrix of the principal component is close to 1 or near 0, the principal components can explain the variables more systematically [18].From Table 7, it can be seen that the first principal component PC_1 combines the plant height, stem diameter, leaf width, yield, dry weight, chlorophyll content, crude fiber content and soluble sugar content of leek. The second principal component PC_2 combines the soluble protein content, Vc content and allicin content of leek, with 3 indexes.

Table 7: Rotated component m atrix of PCA.

	PC_1	PC_2		PC_1	PC_2
Height	0.888	-0.220	Soluble protein	0.539	0.838
Stem diameter	0.981	0.162	Vc	0.241	0.949
Leaf width	0.967	-0.190	Fibre	0.848	-0.464
Yield	0.979	-0.196	Soluble sugar	0.982	-0.044
Dry weight to fresh weight	0.865	-0.179	Garlicin	0.088	0.948
Chlorophyll	-0.812	-0.294			

From Figure 5, we can visually see the relationship between PC_1 and PC_2 in the first crop under different light conditions: RB_2 treatment falls within the positive range of PC_1 and PC_2, indicating that the quality of the chives cultured under the light quality is better The RB_3 and RB_4 treatments all fell in the fourth section of PC_1, which indicated that the leek was less soluble in soluble protein content, Vc content and allicin content, and the other indexes were better. RB_1 treatment the second interval, in contrast to RB_3 and RB_4 processing.

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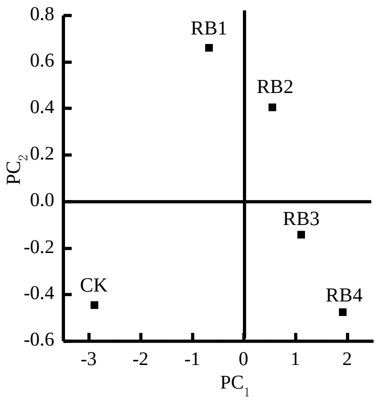

Figure 5: PCA scores for the first crop of Chinese chives on PC1 and PC2

3.5 Comprehensive Score of Different Red / Blue Ratio of Light Quality

According to the integrated principal component function model [19] $F = \sum_{j=1}^{m} b_j Z_j$ b is the contribution rate; m is the number of main components; Z is the main component, the comprehensive principal component score is calculated and the comprehensive score of the different chives under different red / blue ratio light quality is calculated. The results are shown in Figure 6, the comprehensive score of different stubble leek RB4 treatment were the highest, the score was 1.44, 2.17, 1.35, 2.00, significantly higher than other treatments, RB_4 treatment in the whole growth period of leek best comprehensive performance. CK scores were the lowest; the scores were -3.34, -2.84, -3.29, - 2.88. The sum of the scores of each treatment is RB_4> RB_2> RB_3> RB_1> CK.

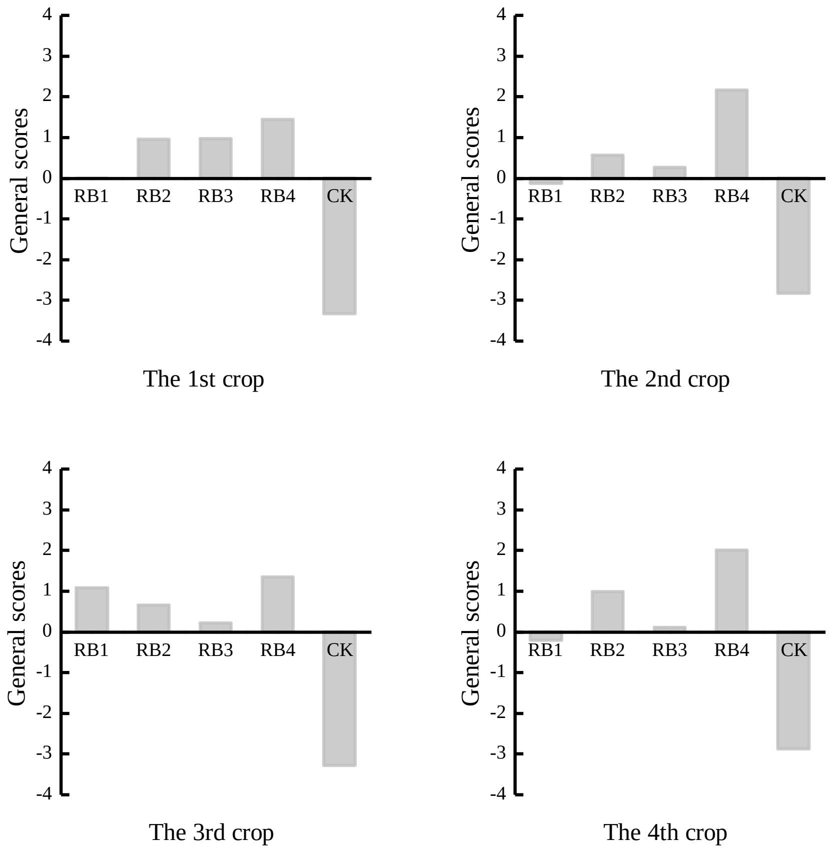

Figure 6: Comprehensive score map of each processing period in Chinese chives growth cycle

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4. Conclusion

Therefore, in the process of leek cultivation, the combination of red and blue ratio of 7:1 combination of light to improve the growth of leek and nutritional quality is of great significance. As a new type of plant growth light, LED lamps has many advantages, but only the suitable proportion of red and blue can maximize the growth and nutritional quality potential of plants.Future experiment could be added more different red and blue light ratio of light quality, and to detect more nutritional quality indicators, and further explore the red and blue light on the role of leeks and other vegetables. In the experiment, the content of V_C in chives was decreased, which was to be further studied.

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