The Influence of Light Wavelengths Toward the Growth of *Brassica rapa L.*

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The Influence of Light Wavelengths Toward the Growth of *Brassica rapa L.*

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Abstract. This research aims to analyze the influence of wavelength from light source on growth of *Brassica rapa L* (pak choi). The lamps used in the research were 11-watt UV light, 8-watt white LED light, red LED light, green and blue 3-watt LED lights, and 150-watt infrared light, placed in boxes except infrared one. The irradiation was done in the growth box made from cardboard with size of 23 cm × 27 cm × 40 cm for 9 hours every day. The measurement done was a biometric measurement by measuring stem height, leaves width and their numbers. The observations were done for 14 days starting from the first day of planting. From the measurement result, the pak choi can grow well on white LED light. While in other light sources, it cannot grow well due the lack in wavelength needed by the plant. The experiment was further carried out by combining white LED light with blue, red and UV. The growth box was made larger with a size of 40 cm × 27 cm × 46 cm. The experimental result showed that all pak choi plants can grow well. Light using a combination of lights was useful in the development and the growth of pak choi. From the three treatments, pak choi with white LED light and UV showed faster growth for width, length and number of leaves.

1. Introduction

Light plays a very important role in plant growth and development. Plants need light as the main energy source in photosynthesis. Currently many artificial lighting systems have been developed to meet the light requirements of plants, such as the use of incandescent light, fluorescent light, halogen light to the newest, energy-efficient LEDs [1]. Lights with wavelengths that match the needs of plants will greatly help plant growth and development. Plant growth is very influenced by the spectrum of light received by the plant. The light spectrum can affect the morphological patterns of plant seeds [2]. In general, light sources used for research on plants are lights that have a wavelength in the range of visible light. High-level plants besides being very effective in utilizing light for photosynthesis, they also have the ability to feel and respond to a much wider spectrum, including UV and far-red [2]. Therefore, in this study besides using lights with several color spectrum, UV and infrared lights will also be used. In this study, the object of the research was vegetable species, namely pak choi (*Brasicca rapa L*). Pak choi is a type of vegetable that is widely cultivated in Indonesia. Biometric measurements were then made on the growth of pak choi plants to observe the effect of the wavelength of the light on the growth rate.

2. Research Methods

The light wavelength used in this study was measured using a Vernier SpectroVis® Plus Spectrophotometer and fluorometer. These are light wavelength graphs from each light.

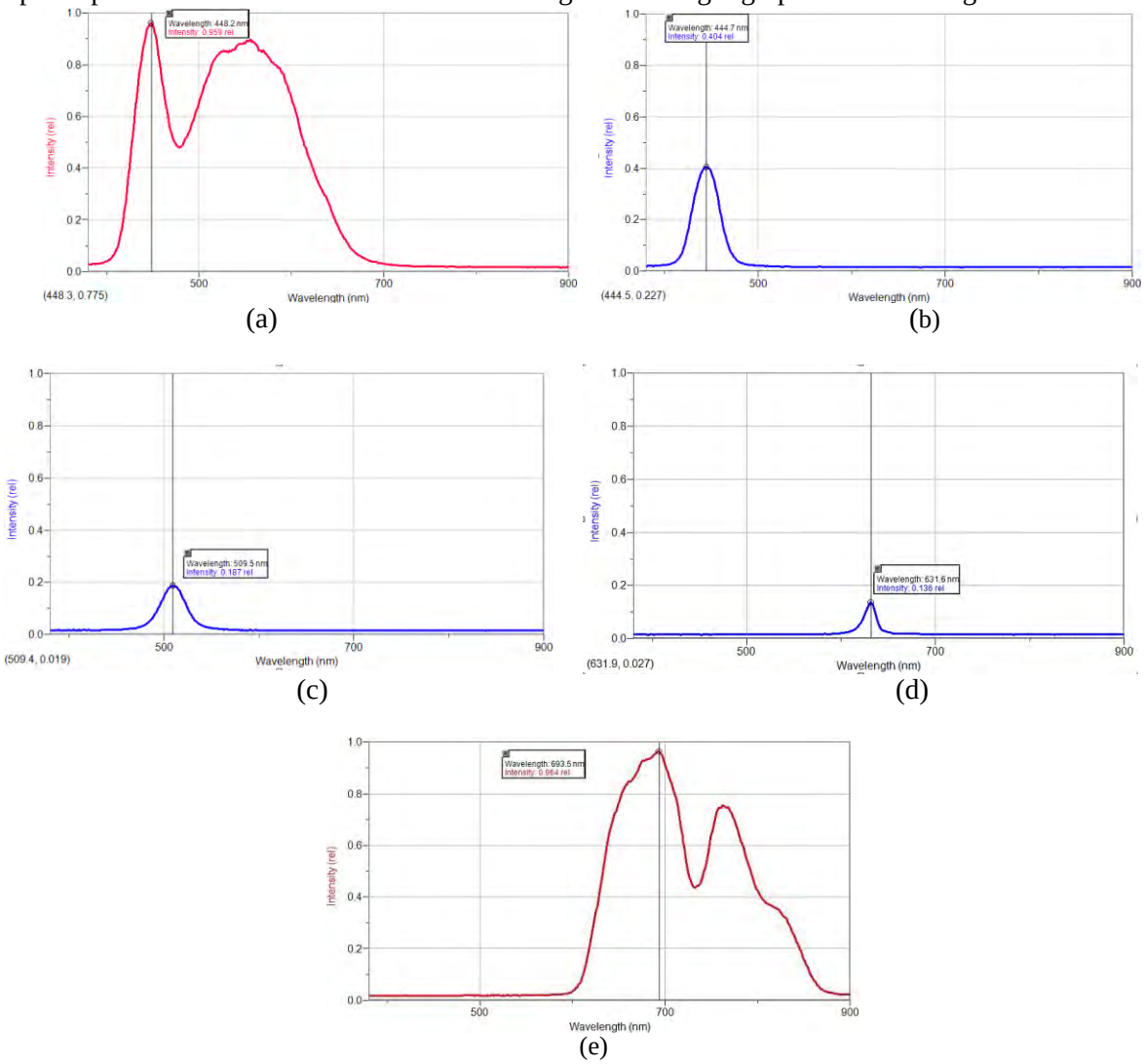

Figure 1. Light wavelengths of light (a) white LEDs, (b) blue LEDs , (c) Green LEDs, (d) red LEDs, (e) Infrared.

Wavelength of the white LED light in visible light range is 400-700 nm with the peak wavelength at 448.2 nm and 555.7 nm. Blue LED lights have a peak wavelength of 444.7 nm with 7.98% FWHM. Green LEDs have a peak wavelength of 509.5 nm with a FWHM of 7.18%. Red LEDs have a peak wavelength of 631.6 nm FWHM 2.69%. The wavelength of infrared lights in the wavelength range is 600-875 nm with a peak wavelength at 693.5 nm and 762.6 nm. The wavelength of UV light cannot be measured using this spectrophotometer because wavelength range that can be measured is only in the range 380-950 nm. UV lights commonly used to money detector which has 365 nm radiation. The growth box is made of cardboard boxes with size 27 cm × 23 cm × 40 cm. For experiments with a combination of two ligths cardboard boxes with size 40 cm × 27 cm × 46 cm. The lighting process at the facility is carried out every day for 9 hours, from 08.00 to 17.00 WIB. Observations were made within 14 days. Control variables in the study are temperature, air humidity, lots of water in the watering process, soil and fertilizer given are also the same for all plants.

3. Results and Discussion

3.1 Analysis of plant growth using one lighting source.

The measurement results in the form of biometric measurements that will be analyzed to determine the growth pattern of pak choi plants in terms of the lighting process. Leaves measured are leaves that first grow on germination. Measurements begin on the third day after the plants begin to germinate. Plant measurements are carried out every day for 14 days of planting.

3.1.1 Analysis of stem heigth using one ligth source.

Table 1. Stems heigth using one ligth source.

Lights	Stem heigth each day (cm)											
	h 1	**h 2**	**h 3**	**h 4**	**h 5**	**h 6**	**h 7**	**h 8**	**h 9**	**h 10**	**h 11**	**h 12**
UV	1.33	3.13	5.08	6.15	7.28	7.63	7.98	8.08	8.15	8.18	8.23	8.23
White LED	1.13	2.70	3.83	4.50	4.83	4.95	5.05	5.23	5.33	5.33	5.33	5.38
Green LED	1.58	3.73	5.75	6.95	7.75	8.05	8.35	8.40	8.40	8.40	8.40	8.40
Blue LED	1.45	3.38	5.68	6.78	7.50	7.80	7.98	8.08	8.10	8.10	8.10	8.18
Red LED	1.50	3.00	4.88	6.35	6.80	7.03	7.25	7.25	7.30	7.33	7.33	7.33
Infrared	0.00	0.60	1.38	1.60	1.88	2.33	2.73	2.88	2.90	3.13	3.13	3.53

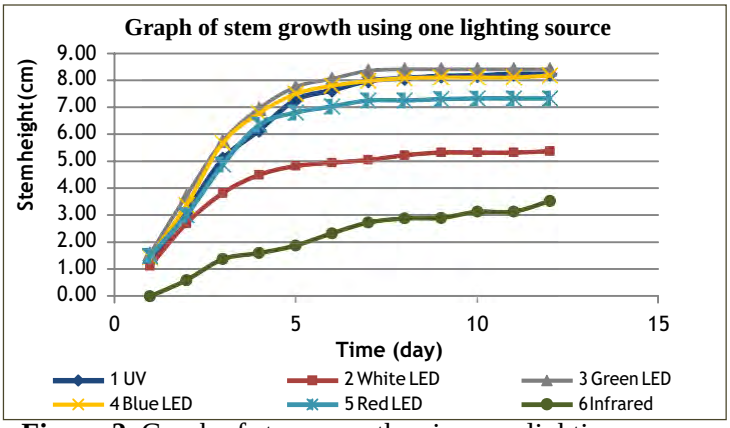

Figure 2. Graph of stem growth using one lighting source.

Based on Figure 2. shows that plants using white light, the stems do not grow as high as other lighting. This is due to the inhibition of auxin hormones in plants, which causes the plants to grow slowly. Light with a wavelength of 400-520 nm consisting of light violet, blue and green has a strong effect on vegetative growth of plants. For light with a wavelength (720-1000 nm) far red / infrared, germination occurs in this light range, but very little absorption occurs in this wave band. For infrared, absorption the light in this area was changed to heat [3]. In this experiments, the plants under infrared lighting, did not grow evenly. The heat produced from this light causes the germination process of the pak choi plant to be slow. Based on the graph it can also be seen that the plants are under the same green, blue and UV height of the plant. However, plants under green lighting, have stems that grow taller but are thinnest and wither than other lighting plants.

3.1.2 Analysis of leaf width using one lighting source

Table 2. Leaf width using one lighting source.

Lights	Leaf width each day (cm)											
	***w* 1**	***w* 2**	***w* 3**	***w* 4**	***w* 5**	***w* 6**	***w* 7**	***w* 8**	***w* 9**	***w* 10**	***w* 11**	***w* 12**
UV	0.40	0.45	0.45	0.53	0.53	0.60	0.60	0.60	0.60	0.60	0.60	0.60
White LED	0.50	0.70	0.83	0.85	0.95	1.05	1.05	1.05	1.08	1.08	1.08	1.08
Green LED	0.35	0.43	0.50	0.53	0.55	0.58	0.65	0.65	0.65	0.65	0.65	0.65
Blue LED	0.33	0.43	0.48	0.50	0.55	0.55	0.58	0.60	0.60	0.60	0.60	0.60
Red LED	0.45	0.53	0.55	0.60	0.63	0.65	0.68	0.70	0.70	0.70	0.70	0.70
Infrared	0.00	0.23	0.25	0.35	0.53	0.58	0.60	0.63	0.65	0.80	0.83	0.83

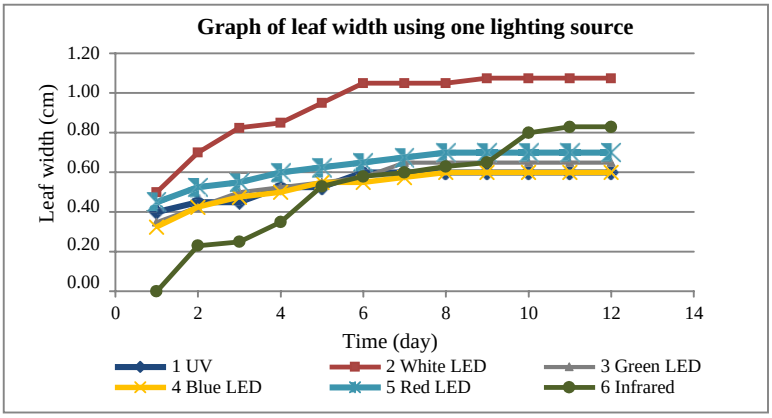

Figure 3. Graph of leaf width using one lighting source.

The light spectrum is one of the external factors that influence plant growth. In this experiment, lighting with white light provides better leaf development results than other lighting. The same thing happened in the study of Lalge et al. [4], the average leaf area in *Cannabis sativa L*. plants was larger using white LED lighting than blue-red lighting. Which shows a fairly high increase for plants under white lighting compared to other light spectrum. Report by Acero [5], also gets the same results, plants with white fluorescent light give the highest average leaf length, this light can be used as artificial light in the growth box. Because white light consists of all color spectrum, so it provides some spectrum of light needed by plants. Based on table 1. and Figure 3. plants that use UV, green and blue lighting experience small leaf width growth. However, the plants that use the green light of the leaves are the thinnest and quickly wither.

3.1.3 The number and color of leaves after 14 days.

After 14 days observation, pak choi plants were given a white light had more leaves than other light spectra. Some plants have four leaves. In other lighting all plants ony have two leaves. That shows that the use of white LED light in this experiment is most influential on pak choi growth.

Tabel 3. Leaf Colors on 14th day

Lights	Leaf Color
UV	light green
White LED	green
Green LED	yellow
Blue LED	light green
Red LED	light green
Infrared	green

Changes in leaf color were also observed. After a few days in some plants, the color of the leaves become light green. In white and infrared lights , the leaves color is still green. The color of leaves on pak choi plants under green lighting has yellow leaves. Plant pigments have a certain wave absorption pattern known as the absorption spectrum. According to Lakitan [6], the leaves of most species absorb more than 90% of purple and blue light, as well as for orange and red light. Green light by chlorophyll is reflected or continued. Lack of light absorption by plants that grow using green light, can cause photosynthetic disorders in plants, so plants become lack of energy to grow properly. Based on the analysis of stem height, width, number and color of leaves, it can be concluded that planting using white light gives a good growth effect on pak choi plants so that it can be used as artificial lighting.

3.2 Analysis of plants growth using a combination of two lighting sources

Based on the results of the experiment using one light source, an experiment was conducted using a combination of two light sources. in experiments using a single light source, white LED lights have a better effect on pakcoy plants because of the complete spectrum of visible light. So for the next experiment this lamp is used in each growth box. The lights used are white, red and blue LEDs and UV lights. Infrared lights and green LED lights are not used anymore. Infrared lights are not used anymore in this experiment because the growth of pakcoy plants irradiated by infrared lights does not grow evenly. Green LED lights are also not used anymore because the growth of the pakcoy plant is not good, the plants have thin stems and the leaves of the plant are yellow and withered.

3.2.1 Analysis of stem heigth using a combination of two lighting sources

Table 4. Stem height using a combination of two lighting sources.

Lamps	Stem heigth each day (cm)											
	h 1	***h 2***	***h 3***	***h 4***	***h 5***	***h 6***	***h 7***	***h 8***	***h 9***	***h 10***	***h 11***	***h 12***
White + blue	1.25	3.33	4.53	5.18	5.45	5.63	5.78	5.78	5.88	6.00	6.08	6.13
White + UV	1.43	3.03	3.78	4.38	4.48	4.65	4.83	5.00	5.05	5.18	5.20	5.28
White + red	1.13	2.83	4.08	4.60	4.80	5.00	5.05	5.18	5.25	5.38	5.43	5.55

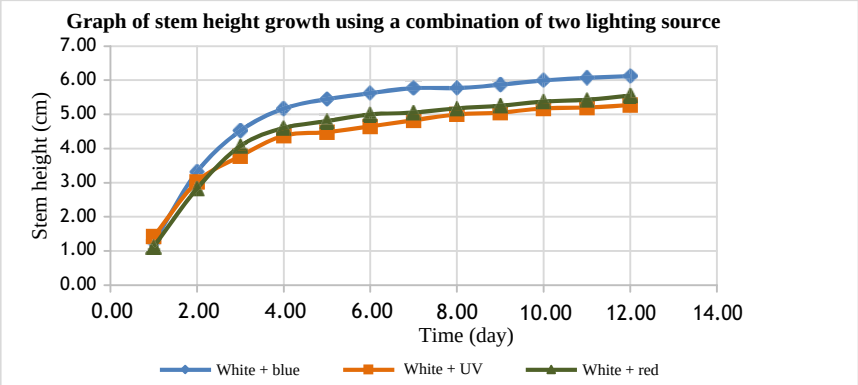

Figure 4. Graph of stem height growth using a combination of two lighingt sources.

Based on the data in table 1 we can see the average height after 14 days of plants for UV light 8.23 cm, white light 5.38 cm, blue light 8.18 cm, and red light 7.33 cm. Based on Table 4. after the light is combined the average height of the plant for white + blue light 6.13 cm, white light + UV 5.28 cm and white + red light 5.55 cm. From these results can be seen that plants use white LED lighting, both white LEDs and a combination of white light and other light, the stem of the plant does not grow as high if only using blue or red light. This is because, in plants that get enough lighting there is a work inhibition of the hormone auxin by light which can cause the stem to grow more slowly. And when compared to the three lighting combinations, the highest plants are plants that use white + blue lighting. The inhibition of the action of auxin hormones is more on plants that use white light + red and white light + UV.

3.2.2 Analysis leaf width and leaf length of the pak choi plants using a combination of two lighting sources.

Table 5. Plant leaf width using a combination of two lighting sources.

Lights	**Leaf width each day (cm)**											
	***w* 1**	***w* 2**	***w* 3**	***w* 4**	***w* 5**	***w* 6**	***w* 7**	***w* 8**	***w* 9**	***w* 10**	***w* 11**	***w* 12**
White + blue	0.48	0.73	0.98	1.08	1.18	1.23	1.25	1.30	1.33	1.33	1.35	1.35
White + UV	0.48	0.83	1.05	1.18	1.25	1.30	1.35	1.38	1.38	1.40	1.43	1.43
White + red	0.45	0.70	0.80	0.98	1.05	1.13	1.20	1.23	1.23	1.30	1.33	1.33

In the experiment using two light sources, additional measurements were made, that is the measurement of leaf length. This is done for observe more detailed plant growth if two light sources are used in the growth box.

Table 6. Leaf length using a combination of two lighting sources.

Lights	**Leaf length each day (cm)**											
	***l* 1**	***l* 2**	***l* 3**	***l* 4**	***l* 5**	***l* 6**	***l* 7**	***l* 8**	***l* 9**	***l* 10**	***l* 11**	***l* 12**
White + blue	0.33	0.35	0.55	0.68	0.68	0.78	0.80	0.80	0.85	0.85	0.85	0.90
White + UV	0.30	0.50	0.63	0.75	0.80	0.85	0.90	0.95	0.95	0.95	0.98	1.00
White + red	0.30	0.38	0.53	0.58	0.63	0.70	0.78	0.80	0.83	0.85	0.85	0.85

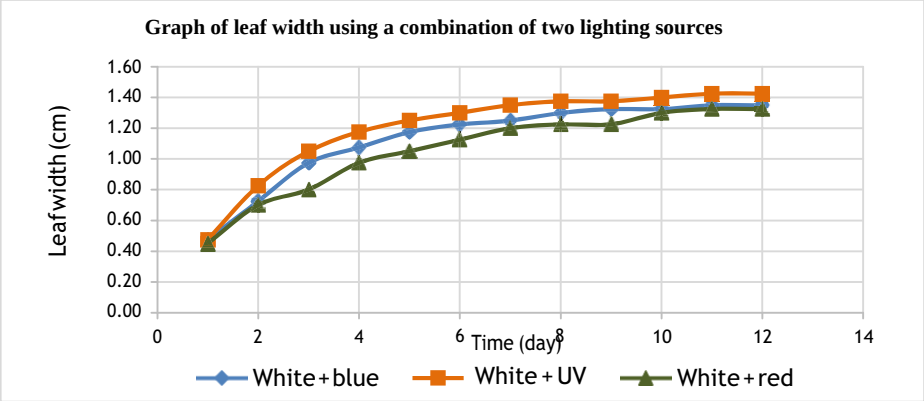

Figure 5. Graph of leaf width using a combination of two lighting sources.

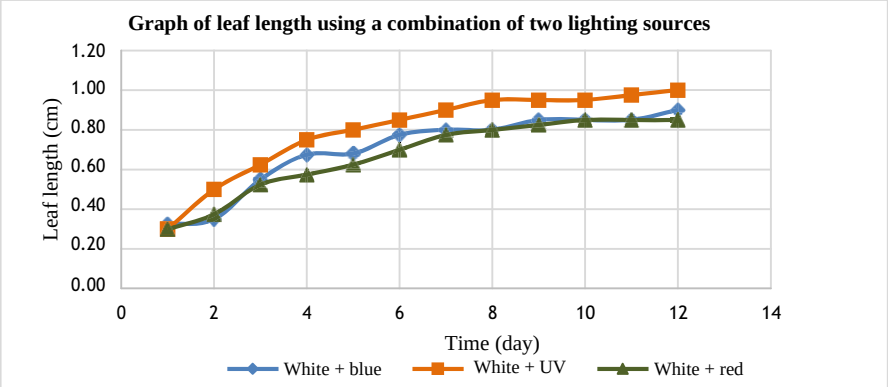

Figure 6. Graph of leaf growth using a combination of two lighting sources.

Based on the average leaf width of the pak choi plants in the three growth box all showed good leaf development. The average leaf width of the pak choi plant after 14 days of the fastest development was the plant under the white + UV light. It turns out that combining two light sources with different light spectrum gives a good effect for plants. Based on the data in Table 6. and the graph in Figure 6. the results of measurements for leaf length carried out every day for 14 days planting the width of the leaves from the three treatments also did not occur significantly. The average leaf width of the pak choi plant after 14 days, the fastest development was the plant under the lighting of white + UV light.

3.2.3 Analyze the number of leaves and leaves colour using a combination of two lighting sources

Tabel 7. Number of leaves using a combination of two lighting sources after 14 days

Lights	Number of leaves on 4 plant samples			
	1	**2**	**3**	**4**
white + blue LEDs	4	4	4	4
white LED + UV	5	5	5	5
white + red LEDs	4	4	4	4

The plants with the most number of leaves are pak choi plants using a combination of white + UV LED light with a total of 5 leaves. While plants using other lighting has 4 leaves after 14 days. Pak choi growth in white + UV LED lighting is faster than pak choi plant growth in white + blue and white + red

LED lighting. And all plant leaves using combination of two lighting sources are green. A combination of white light lamps and UV lights can be used as artificial light for plants indoors.

There are two ways light controls plant growth. The first is through photosynthesis. Long-term growth requires an adequate energy supply, where in green plants this energy is provided by the capture of light energy in photosynthesis. Photosynthesis provides the basic resources (energy and carbon bonds) needed for the growth of green plants continuously. Secondly, photocontrol growth also occurs through photomorphogenesis pigments. This pigment detects one or more environmental light conditions (such as quality, quantity, direction and duration of light) and modulates growth in response to plants for this condition. The effect of light is marked by the size and shape of the plant. While photomorphogenetic pigments regulate the rate and direction of growth of various plant organs. In short, photosynthesis provides important raw materials needed for growth but photomorphogenetic pigments modulate and control the growth process itself [7]. Lighting that has a complete wavelength needed by plants can make plants grow well. A complete spectrum of light in white light combined with UV light can increase plant growth. UV and blue light are short wavelength light that has many energetic photons compared to red and orange light with longer waves [6]. The energy generated from the UV light spectrum combined with this white light can provide photosynthetic energy to plants for the continued growth of the pak choi plant.

4. Conclusion

Based on the result it can be seen that the growth of pak choi plants is affected by the light spectrum. Pak choi plants can grow well in 8 watt white LED lights. Experiments combining two lights with different light spectrums have a good influence on the growth of pak choi plants. The experimental results show that all pak choi plants can grow well. Of the three treatments, pak choi plants in white light and UV lighting showed faster pak choi plant growth for width, length and number of leaves.

5. References

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