EFFECT OF DIFFERENT LIGHTS USED ON GREEN AMARANTHUS GROWTH

NURUL IZZATI BINTI ABDUL AZIZ

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EFFECT OF DIFFERENT LIGHTS USED ON GREEN AMARANTHUS GROWTH

by

NURUL IZZATI BINTI ABDUL AZIZ

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KESAN PENGGUNAAN LAMPU YANG BERBEZA TERHADAP PERTUMBUHAN BAYAM

ABSTRAK

Permintaan sayur-sayuran di Malaysia semakin meningkat. Walaubagaimanapun, tanah di Malaysia tidak mencukupi untuk menanam sayur-sayuran selain harga upah dan racun serangga yang juga turut meningkat. Menurut data oleh FAMA, penggunaan sayur-sayuran per kapita merekodkan peningkatan yang stabil dengan 1% setiap tahun antara tahun 2009 dan 2014. Oleh itu, salah satu cara yang boleh digunakan untuk menghasilkan lebih banyak sayur terutama bayam, adalah tanam menggunakan lampu. Lima lampu yang berbeza telah digunakan dalam penyelidikan ini bagi mengkaji kadar pertumbuhan bayam. Antara lampu yang digunakan ialah lampu putih, lampu merah, lampu biru, lampu kuning dan matahari sebagai pemboleh ubah malar. Jenama yang digunakan ialah Philip dengan kuasa 35 wat. Eksperimen ini terbahagi kepada dua fasa iaitu fasa percambahan dan fasa pertumbuhan. Selepas 15 hari menanam bayam, keputusan dicatat. Berdasarkan keputusan, lampu merah didapati sebagai lampu yang paling berkesan digunakan untuk pertumbuhan bayam di mana ia menunjukkan kadar pertumbuhan yang paling tinggi. Selain itu, pH 5.6012 adalah lebih efektif berbanding 7.0 dan 8.0123. Hal ini demikian kerana boleh dilihat apabila semua aspek yang telah dikaji menunjukkan keputusan yang paling tinggi untuk pH 5.6012.

EFFECT OF DIFFERENT LIGHTS USED ON GREEN AMARANTHUS GROWTH

ABSTRACT

The demand for vegetables in Malaysia is increasing. However, Malaysia does not have enough land to plant crops besides the price labor and pesticides also increasing. According to the data by FAMA, per capita consumption for vegetables recorded a steady increase of about 1% each year between 2009 and 2014. Therefore, one of the ways that can be used to produce more vegetables especially spinach, is by growing them using lights. Five different lights were used in this research to study the growth rate of green amaranth. The lights are white light, red light, blue light, yellow light and sunlight as a control variable. The model used is Philip with 35 watt each. The experiment is divided in to stage, germination stage and growing stage. After 15 days of planting the green amaranth or spinach, the results were obtained. Based on the results, red light is the most effective light for the growth of green amaranth as it shows red light has the highest growth rate. Besides, pH of 5.6012 is more effective compared to 7.0 and 8.0123. This can be seen when all aspects that were being studied show highest result for pH 5.6012.

CHAPTER 1: INTRODUCTION

1.1 Research Background

Spinach is a dark green leafy vegetable that belongs to the *Amaranthaceae* family, along with beetroot and Swiss chard (Spinach, 2018). According to The Seed Collection page, the scientific name for spinach is called *Amaranthus Tricolor* or its common name is green amaranth with round leaves (Amaranth-Green Leaf, 2018). Green amaranth has large tender green that are sweet in flavour and quite popular in Asian cuisine which used for soups, stews and stir-fries (Amaranth-Green Leaf, 2018). Besides, it is fast growing and heat tolerant. The leaves of all three plants share a similar taste profile which is an annual plant that grows to about 30cm (Spinach, 2018).The composition for raw spinach is 91% water, 4% carbohydrates, 3% protein, and contains negligible fat (Is Spinach good for you?, 2018). Spinach is known as a functional food due to its diverse nutritional composition, that includes vitamins and minerals, and also for its phytochemicals and bioactive which promote health beyond basic nutrition (Is Spinach good for you?, 2018).

Figure 1.1: Green amaranth with round leaves

Moreover, there were recent studies showed that green amaranth with antioxidant substances show that it can slow the progression of Alzheimer's disease (Feng, et al, 2012) and (Nascimento, 2014). This review is an attempt to get the information on various ethnomedicinal uses of spinach for anti-Alzheimer's disease. This disease is a multifactorial neurodegenerative disorder which its causes and the progression are still not well understood (Ye, 2012).

Light is an important environmental factor for plant growth as it is primary source energy (Noaya, 2008). Without light a plant cannot grow, reproduce, or photosynthesize. Plants to make use of the different colors found in visible light to control different aspects of their growth (Introduction of Mung Bean, 2018). Different wavelengths of light can inhibit growth and flowering in plants (Introduction of Mung Bean, 2018). The quality of light and the pH of medium used are essential for the growth and other responses of plants. Changes in colour of light influenced the parameters of the physiology and morphology of plant (Xiao, 2013). Light emitting

diode (LED) is being used as a new light source recently. A LED has good life performance and also has energy-saving ability. The effects of light on the plant growth have been studied for a long time. Red light helps in germination and photosynthesis of lettuce (Flint and McAllister, 1937) and (Balegh SE. and Biddulph O. 1970). For blue light, it affects stomatal opening and chloroplast development (Takemiya, 2017). Responses to green light are typically low-light responses that it may slows down or stop the plant development, but it can brings positive effects in certain conditions (Folta and Maruhnich, 2007) and (Terashima, 2009).

The natural products from medicinal plants have gained interests among researchers around the world for new drugs because of their positive bioactivity effects (Sasidharan, 2011). Besides, the medicinal plants have been used to enhance cognitive function and to alleviate other symptoms that is related with Alzheimer's disease (Rao, 2012). Spinach is one of the most important antioxidant plants that is usually consumed either fresh or frozen leaves mainly for healthy purpose.

1.2 Problem Statement

The Malaysian agro-food industry is increasingly market-driven as the consumers are becoming more health-conscious and they are consuming more vegetables (Tey, 2009). This shows that the demand for vegetables at a disaggregated level. On the other hand, Malaysia also imports vegetables. One of the reasons is Malaysia does not have enough land to plant crops and not to mention, the price labor and pesticides have all shot up. In 2014, Malaysia’s per capita consumption for vegetables was 58.5% which is 1.2% increased from 2013. According to the data by FAMA, per capita consumption for vegetables recorded a steady increase of about 1% each year between 2009 and 2014 (Ruban, 2016). Therefore, one of the ways that can be

used to increase production rate by optimizing the parameter that affect the growth rate of green amaranth.

This study focused on the green amaranth growth by using different colour of lights and also different pH range. Besides, this experiment also studies the length of green amaranth exposure to the lights. Based on the problem statement stated above, the demand of green amaranth in Malaysia is increasing for widely purpose and this will increased the production. In order to catch up with those demands, this research is to investigate which light and condition that can make the plant growth.

1.3 Research Objectives

There three objectives in this experiment are:

1) To study the effect of different light on green amaranth growth.
2) To study the pH of the medium on green amaranth growth.
3) To study the effect of the length of exposure towards the green amaranth growth.

1.4 Organization of Thesis

The thesis is divided into five chapters. This is providing the general information and details of the works done as well as findings of the research. These chapters are Introduction, Literature Review, Methodology, Results and Discussion and last is the Conclusions and Recommendations.

Chapter one is the introduction of spinach, problem statement, research objectives, scopes of study and thesis organization.

Chapter 2 reviews the Light Emitting Diode (LED) on the plant growth. Then, Chapter 3 is about the methodology used throughout the experiments which are detailed out. This chapter is divided into three sections (3.1 to 3.3). The first two sections are on research methodology flow and all chemicals and materials used in this study. The third section is for data analysis that can be used and calculated for the next two chapters which are Chapter 4 and 5.

CHAPTER 2: LITERATURE REVIEW

2.1 Light Emitting Diode with different colour

The use of different lights in controlled environments has led to the discovery of changes in plant morphology caused by spectral quality (Tracy, 2001). The photomorphogenic changes which caused by altered phytochrome photoequilibrium (PPE) are well documented (Ballare, 1995). These studies suggest that differences in the blue portion of the spectrum effect the morphological differences but unfortunately, nonblue wavelengths also varied with types of lights in these studies, so definitive conclusions have to be questioned (Tracy, 2001).In a companion paper (Dougher, 2001), they compared lettuce growth under high-pressure sodium (HPS) lamps with metal halide (MH) lamps that were filtered to 6% blue. The chlorophyll concentration, dry mass, leaf area and also specific leaf area (SLA) were sensitive to the remaining spectral output (Tracy, 2001).

As discussed in the companion paper (Dougher, 2001), some of the plants responses are determined by the quantity of the blue photons other than the fraction of blue photons. However, both 6% blue treatments had the same amount of blue photons at each PPF: 12 μmol m^{-2} s^{-1} blue at 200 μmol m^{-2} s^{-1} or 30 μmol m^{-2} s^{-1} blue at 500 μmol m^{-2} s^{-1} as shown in Table 2.1. The quantity of blue photons could not have caused the differences in growth between the two 6% blue treatments (Tracy, et al. 2001).

Table 2.1: Comparison for the blue photons

PFF	Lamp type	Blue light			UV		Ratios				Yellow light
		Fraction (% of 320–700 nm)	Photons (320–496 nm) (μmol m^{-2} s^{-1})	Phototropic* (300–520 nm) (μmol m^{-2} s^{-1})	Fraction (% of 320–496 nm)	Photons (320–400 nm) (μmol m^{-2} s^{-1})	PFE (P_{fr}/P_{total})	R:FR 600–700 nm/ 700–800 nm	B:R 320–496 nm/ 600–700 nm	BFR 320–496 nm/ 720–800 nm	580–600 nm) (% of 320–700 nm)
200	HPS	0.1	0.2	0.1	0.5	0.001	0.86	2.80	0.008	0.012	32
	HPS	1.5	3	1.8	3.3	0.1	0.85	2.71	0.033	0.155	26
	HPS	6†	12	6.8	3.7	0.44	0.86	2.86	0.131	0.661	25
	MH	6	12	6.3	12.0	1.44	0.84	4.39	0.220	1.106	27
	MH	13	24	13	16.6	3.98	0.83	4.15	0.451	2.193	25
	MH	26†	52	28	14.9	7.76	0.82	5.11	1.209	7.818	19
500	HPS	0.1	0.5	0.3	0.5	0.0025	0.86	2.80	0.008	0.012	32
	HPS	1.5	7.5	4.1	3.3	0.25	0.85	2.71	0.033	0.155	26
	HPS	6†	30	17	3.7	1.10	0.85	2.86	0.130	0.661	25
	MH	6	30	16	12.0	3.60	0.85	4.39	0.220	1.306	27
	MH	12	60	31	16.6	9.95	0.84	4.15	0.453	2.193	25
	MH	26†	130	71	14.9	19.40	0.82	5.11	1.209	7.818	19

*Weighting factors from Baskin and Iino (10). PFF = photosynthetic photon flux; PFE = phytochrome photoequilibrium.
†Blue fraction from the lamp filtered only with tempered glass and water, others filtered with tempered glass, water, and yellow cellulose triacetate.

The quantity of blue photons may not have caused the differences in growth between the two 6% blue treatments. This phototropic response curve unequally weights the different wavelengths from 300 to 520 nm based on curvature response of alfalfa seedlings. Therefore, differences in growth between 6% blue HPS and 6% blue MH did not related to phototropic blue levels (Tracy, et al. 2001).

The response curve in the journal quickly becomes less continuous when the yellow wavelength range is altered by adding, subtracting or shifting wavelengths. From this, the yellow light (580–600 nm) seems to inhibit the lettuce growth. Although there is no known relationship between human perception of color and plant physiological response, 580– 600 nm is generally considered to be yellow light (Tracy, et al. 2001).

On the other hand, this paper (Kaneko et al, 2007) did research on three types of different plant which were spinach, komatsuna and lettuce. The effect of light quality on shoot dry weight was quite different depending on the plant species. An irradiation of blue LED was not suitable for biomass production of spinach. The extremely smaller leaf area should be related to the decreased dry weight. This smaller leaf area was not accompanied by a smaller number of leaves which mean that irradiation of blue LED inhibits the expansion of leaves. Extension in the vertical and horizontal directions of a leaf is controlled by different genes (Tsukaya, 1998). Irradiation of blue LED might give cause imbalance in expression of these genes, which may result in expansion of small leaves.

Only the total dry weight of komatsuna was promoted by the radiation of red LED compared with the irradiation of white LED. This promotion of biomass productivity seems to be due to the enlargement of the leaf area under red LED.

Irradiation of red LED is effective for simply promoting edible biomass production. Furthermore, the cultivation period could be shortened by irradiation of red LED.

Irradiation containing blue LED was more effective compared to white LED in increasing L-ascorbic acid content in the study, especially in leaf lettuce plants. Ascorbic acid is synthesized via a sequence of hexose precursors that primarily involve D-glucose (Toledo et al., 2003) and several metabolic pathways leading to ascorbic acid biosynthesis from D-glucose in higher plants have been proposed (Davey at al., 1999). Irrespective of the plant species or light quality treatment there was no correlation between the ascorbic acid content and the soluble sugar content. It is unlikely then that the high content of L-ascorbic acid under blue LED was caused by the large accumulation of sugar precursors.

2.1.1 The effect of blue LED is dependent on the background light

From this journal (Gautam et al., 2015) blue LED plays an important role in mediating stem elongation of LDP (Kim et al., 2002). Blue LED suppressed hypocotyls and stem elongation, like in the LDP Arabidopsis thaliana (Ahmad et al., 2002) as it has been in many researches. Blue LED has also been found to promote stem extension of many LDP (Runkle and Heins, 2001). However, in this experiment (Gautam et al., 2015), we found the shoot length increased when plants were exposed to additional blue LED compared to red LED light.

In other studies, the effect of blue light on plant height has been found to be dependent on the presence or absence of far-red (FR) light. For example, in chrysanthemum removal of blue light resulted in a height increase in the presence of FR

light, meanwhile the removal of blue light did not have a significant effect on plant height in the absence of FR light (Reddy et al., 1996). However, in this journal, they found that the enhanced elongation under blue light was stronger in the presence of FR light (Figure 2.1 and 2.2). Blue light can act via the phytochrome or the other blue light receptors such as cryptochrome or phototropins (Lin, 2000). The strong correlation between stem elongation and PPS in early spring points towards the blue light action via phytochrome (Gautam et al., 2015). It also shows that blue light can work as an "irradiance sensor" and petunia exposed to high blue light under low light conditions, in early spring, it exhibit similar characteristics as plants grown under high light conditions (Terfa et al., 2013).

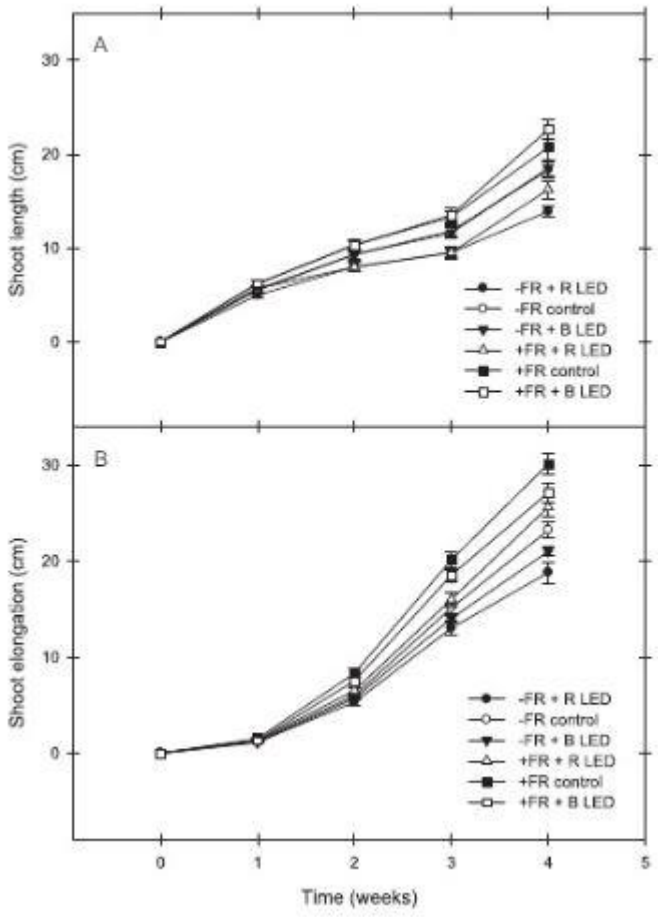

Figure 2.1: The elongation growth of a main side shoot of petunia during early (A) and late spring (B)

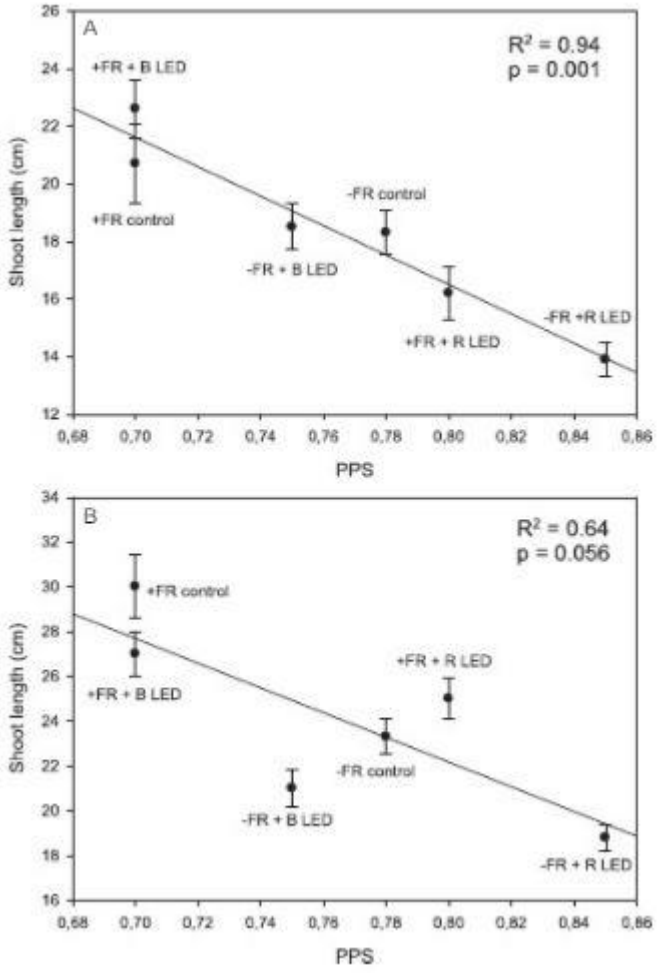

Figure 2.2: Linear relations between phytochrome photostationary state (PPS) and shoot length of petunia after 5 weeks of growth during early (A) and late spring (B)

2.2 Effect of pH/fertilizer

Leifert, et al (1992) reported that micropropagated *Choisya, Daphne, Delphinium, Hemerocallis, Hosta, Iris* and *Photinia* were found to adjust the pH of Murashige and Skoog's plant tissue culture medium with initial pH 5.6 or 3.5 to different values depending on the species tested. The different plant species were found to have distinct pH requirements for optimal growth and rooting rates when plant

growth and rooting rates were determined after the plants had been grown on media initially adjusted or buffered to values between 2.6 and 5.7.

According to Yan, et al (1992), the effect of low pH on net H^+ release and root growth of corn (*Zea mays* L.) and broad bean (*Vicia faba* L.) seedlings was investigated in a short-term experiments at constant pH. The results show that broad bean was more sensitive to low pH than corn with the critical values of pH 4.00 (broad bean) and pH 3.50 (corn) at 1 millimolar Ca^{2+}. As the medium pH declined, both proton release and root growth were progressively inhibited. Besides, additional Ca^{2+} in the root medium helped to overcome the limitations of low pH for net H^+ release and root growth. Therefore, in this paper it concluded that poor root growth at low pH is caused by a lack of net H^+ release that may decrease cytoplasmic pH values. The cause of inhibited net H^+ release at high external H^+ activity is not due to a shortage of energy supply to the H^+ ATPase but instead, a displacement of Ca^{2+} by H^+ at the external side of the plasmalemma may enhance re-entry of H^+ into root cells (Yan, et al, 1992).

On the other journal written by Schubert, S., et al. (1990), the effect of low root medium pH on growth and proton release of field beans *(Vicia faba* L.) was studied in soil and nutrient solution experiments. Proton release by roots causing soil pH to decrease is strongly depended on the proton buffer capacity of 8 different soil types tested in a pot experiment. Meanwhile in soils of high proton buffer capacity no pH decrease during the growth period was detectable, in soils of low buffer capacity pH in the bulk soil dropped from about pH 7.3 to 6.5, 6.3 or 5.8 during growth until maturity. It is concluded that the sensitivity of field beans to low pH is related to a lack of capability to release protons by ATPase activity and this sets limits to nutrient uptake and possibly cytoplasmic pH regulation (Schubert, et al. 1990).

This study was conducted with sugar beet in greenhouse and field at two soil type with different organic matter which is containing 2.4 and 15.9% OM, referred as the low- and high-OM soil conditions in order to investigate seed inoculation of sugar beet, with five N_2-fixing and two phosphate solubilizing bacteria in comparison to control and mineral fertilizers (N and P) applicat. The inoculants strain, soil organic matter content, growing stage, harvest date and growth parameters evaluated were influencing the plant growth responses (Cakmakci, et al, 2006).

2.3 Effect of light exposure

Based on paper written by Garner and Allardio, the plants were grown under different conditions of light exposure, and have made a special study of the tendency to become reproductive or to remain vegetative under varying daily lengths and intensities of exposure. Therefore, several varieties of tobacco and soy bean were used in the experimental work, even though numerous other species of annuals and biennials were used to check the results attained. The time of exposure to light varied in the different tests from 5 hours daily to full daylight, 7 and 12 hours being the exposures period used. As a result, the amount of vegetative growth was proportional to the length of daily exposure to light. The short exposures resulted in short, slender plants of greatly reduced size (Garner and Allardio, 1920). The inception of the flowering or reproductive phase was greatly influenced by length of exposure to light.

As a summary, there are many parameters that affect the plant growth which are different lights, different pH, different medium, different fertilizer and light exposure.

CHAPTER 3: METHODOLOGY

3.1 Experimental Process Flow

Based on the Figure 3.1, it shows the summarization for the experimental set-up. There were three parameters that were being studied which are effect of different lights on plant growth, effect of pH of the medium and effect of length of light exposure on plant. Physiology response is an automatic reaction that triggers a physical response to a stimulus. In this case, it shows the response of the plant towards lights (Fritscher, 2018). Meanwhile, morphological responses is the form and structure of an organism or one its parts (The Free Dictionary). The data were collected in a table form after finishing the experiment. Then, the report was able to be written once the data has plotted. Figure 3.1 shows the experimental procedures to achieve the research objectives.

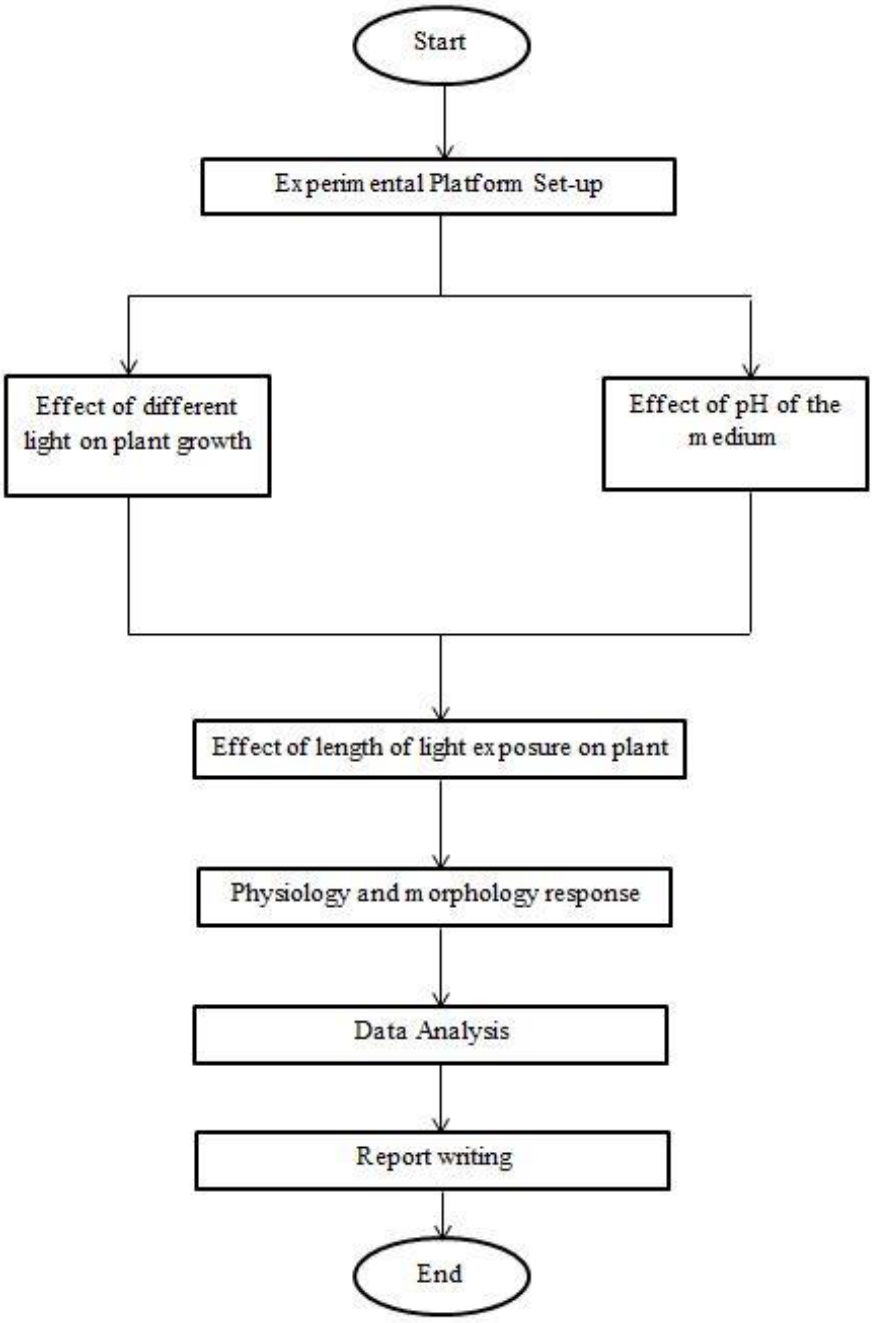

Figure 3.1: Experimental Procedure Flow

3.2 Materials and Methods

3.2.1 Light Source

In the present study, four colours of artificial lights are used which is Philip model and they are all have 35 watt that are consists of white LED, red LED (R), blue LED (B) and yellow LED (Y). Aside from those lights, sunlight is also used as a control in order to compare with the artificial lights.

3.3 Plant Materials and Methods

Spinach or green amaranthus is studied in this project. The experiment is split into two stages. The first stage is germination stage and the second is growth stage.

In the germination stage, the spinach seed is soaked in water at room temperature. This is to make the seed skin soft. After that, put the spinach seeds are spread on the coconut fibre which is soaked in water. This is to give moisture to the seeds so that they can get some water for germination. Those seeds are exposed to sunlight as normal for germination to take place and start. The germination stage is expected to take around 1 – 5 days. The length of the plant shoot is measured every day. In this study, germination stage is considered past once the plant shoot length is more than 3 cm (Nasir, 2009). In the present study, germination last for 5 days and on 6^{th} days, the plants are moved to the growing platform and it is considered going into growing stage as shown in Figure 3.2 and 3.3.

Figure 3.2: Stereofoam box with four holes.

Figure 3.3: In front of strereofoam box

For growth stage, the stereofoam boxes were prepared with minimum nutrient solution level of 10 cm height. Then, the holes were made on the stereofoam cover with diameter for each of the holes is 4 cm and distance between the holes 4 cm. Then, the seed that have passed the germination stage were transferred on the stereofoam box and waters them. For growth stage usually takes about 6 – 9 days (Nasir, 2009). Take the measure of the response variables every day and record them in table.

3.3.1 Nutrient Solution Preparation

For nutrient solution in hydroponic, distilled water is used instead of hard water. This is because hard water or tap water contains ions and other elements that can give harmful effects to a hydroponics system. The hydroponic solution contains macronutrients and micronutrients. The solution is prepared from two different solutions brand *Cilibangi* which are micronutrient (A) and macronutrient (B) as shown in Figure 3.4. The ingredients for micronutrient and macronutrient are stated in a Table 3.1 below:

Table 3.1: Ingredients of micronutrient and macronutrient

Micronutrient (A)	Macronutrient (B)
Calcium nitrate	Nitrogen
Iron	Phosphorus
Potassium nitrate	Potassium
Magnesium sulphate	
Zinc	
Copper	
HiBor Manganese	
Amm molybdate	

Figure 3.4: Solution A and B for fertilizer

10 liter of distilled water was pour into 10 liter basin. Then, 25 ml of micronutrient and 25 ml of macronutrient were measured by using measuring cylinder. The solutions then were mixed together with 10 liter of distilled water. The mixture was stirred. After that, 50 ml of the mixture was taken to be tested with pH meter in order to achieve pH 5.6, 7.0 and 8.0. The values were recorded in the table.

3.3.2 pH adjustment

Check the pH of the hydroponics solution after adding the nutrients using pH meter. Hydroponic is one of the methods used to growing plants without soil. Hydroponics nutrients usually lower the pH balance of neutral water, so you may need to use pH additive to adjust the balance afterward. Pour the nutrients in one by one,

going slowly to prevent overflow, spills, or similar loss of nutrients. Make sure that the cap is securely screwed on or snapped into place and then shake the container by using both hands for 30 to 60 seconds to combine the nutrients. Most plants grow best in a solution that has a pH of 5.7 until 7.0. If the pH is greater than 7, the water is alkaline, so add a few drops of vinegar for each gallon and recheck the pH. If the solution is below 5.7, it is too acidic, so add 1/2 teaspoon baking soda for each gallon and recheck the pH.

CHAPTER 4: RESULT AND DISCUSSION

4.1 Germination stage

In germination stage, 20 seeds of spinach were planted for 5 days. In Table 3, it shows the seeds have been divided into five groups labeled which are A, B, C, D and sun that to be used for different colour of light later. At the beginning, all groups of the seeds are being germinated under the sunlight. From Table 4.1, the results were collected based on the plant shoot height measured.

Table 4.1: Shoot length in cm for germination stage for different groups of seeds.

Day	A	B	C	D	Sun	Average
1	0.12	0.1	0.11	0.12	0.12	0.11
2	0.54	0.48	0.51	0.55	0.54	0.52
3	1.21	1.15	1.25	1.23	1.21	1.21
4	2.61	2.55	2.6	2.58	2.48	2.56
5	3.65	3.52	3.55	3.6	3.57	3.58

Figure 4.1: Image of seeds at second day

4.2 Effect of light colour on the growth rate of green Amaranthus.

A is the seeds that germinate to be experimented under white light. B is for red light, C is for blue light, D is for yellow light and sun is for sunlight. Based on the bar chart plotted in Figure 4.2, this can be seen that the graph shows the growth rate of green amaranth in different lights with pH 5.6012. Day 1 in growth stage is representing the 6th day of the plant growing and it is the same with Day 2 until 10 and the total days the plant was grown is 15 days. Among the 5 different lights, Box B which represents red light shows the highest rate growth compared to white light (A), blue light (C), yellow light (D) and sunlight (E).

According to research conducted before (Balegh and Biddulph, 1970), red light helps in germination and photosynthesis of a plant. Therefore, the result from this experiment proved that the red light can enhanced the growth of green amaranth as well. Meanwhile, the shortest plants height which mean the plants with blue and yellow lights were having the lowest growth rate.

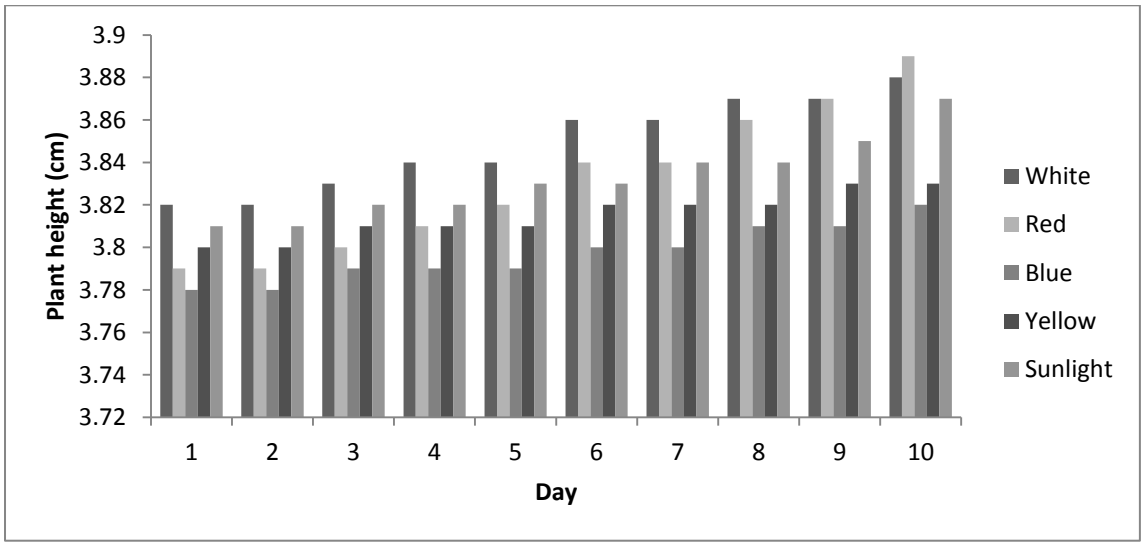

Figure 4.2: Graph of plant height for 5 different lights that has pH of 5.6012