

The Effect of Light Distance on Aeroponic Potato Seed Production in The Tropical High Land

Eni Sumarni^{1✉}, Loekas Soesanto², Widhiatmoko Herry Purnomo³, Priswanto³

¹Agricultural Engineering Study Program, Department of Agricultural Technology, Faculty of Agriculture, Jenderal Sudirman University, Karangwangkal, Purwokerto, INDONESIA.

²Department of Agrotechnology, Faculty of Agriculture, Jenderal Sudirman University, Karangwangkal, Purwokerto, INDONESIA.

³Electrical engineering major. Faculty of Engineering. General Sudirman University, Kalimantan, Purbalingga, INDONESIA.

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ABSTRACT

Aeroponic potato seed production in the highlands during foggy weather is an obstacle in increasing the number of tubers. Research that has been done previously is the addition of artificial light to support the growth and yield of potato seeds in the highlands. Nevertheless, from these results, there were still some plants that did not have optimal growth. It was suspected that the lamp height affects the growth and yield of aeroponic potato plants. The purpose of this study was to determine the effect of lamp distance on artificial lighting on the growth and yield of aeroponic potatoes. The factors that were tried were the height of the lamp from the aeroponic box 110 cm, 120 cm, and 130 cm. The lamps used: 18 Watt red blue LED (RB) and 10 Watt white fluorescent lamp. The design used was a completely randomized design. Growth observation data and results were analyzed by F test followed by Duncan's Multiple Distance Test (DMRT) 5%. The results showed that the combination of RB LED lamps with a height of 110 cm produced the highest number of bulbs of 31,7 per plant. The weight of aeroponic potato tubers in the highlands with the highest yield was obtained from a combination of 110 cm (29,3 g) RB LED lights.

✉Corresponding Author

eni.sumarni@unsoed.ac.id

1. INTRODUCTION

Cultivation techniques in open land depend on the natural environment such as weather, use of pesticides, fertilizers and chemicals. Climate change can reduce crop productivity due to an increase in pests and plant diseases (Wiyono, 2007). The effects of climate change and agricultural production are multidimensional, ranging from resources, agricultural infrastructure, and production systems, to food security, welfare of farmers and society in general (Winarto et al. 2013; Hadi et al., 2010). This also occurs in the production of potato seeds and potatoes for consumption carried out in open fields due to weather fluctuations. Therefore, the aeroponic technology in the greenhouse was chosen in the context of continuity and also to increase production (Sumarni et al., 2019a; 2019b;

2013). The development of aeroponic potato seed production in greenhouses that has been carried out in wet tropical countries, such as Indonesia, can become an attractive and competitive crop industry.

Several uses of greenhouses for commercial crop production and having high-tech production facilities for vegetables or flowers have been developed in several subtropical countries. The greenhouse has heating, cooling, filtration, lighting and can be controlled by a computer to optimize plant growing conditions (Rajesh & Nita, 2016). Greenhouses are widely available in China, Japan and Korea, which are a group of 80% of greenhouses in the world (Tian, 2017). Greenhouses used for potato seed production in wet tropical highlands have not considered roofs with photosynthetically active radiation (PAR) capabilities that support photosynthesis; therefore problems arise when the sunlight intensity entering the greenhouse is low.

Several factors that affect plant growth and development are light, temperature, humidity, water, nutrients, gravity. Light is one of the most important factor because it provides energy for photosynthesis as well as information about the environment. Sunlight provides energy for photosynthesis (Hopkins, 1999). The wavelength of light for photosynthesis (PAR) ranges from 400 nm-700 nm (Tian, 2017). The quality and quantity of light are important for the growth and development of potato plants. Plant growth and development is influenced by light intensity, light quality and lighting duration (Taiz & Ziger, 1991). Previous studies have shown that potato plants that are in lack of light (shade) 50% experienced delayed flowering and decreased number of tubers by 19-44%. The growth and photosynthesis of potato plantlets in vitro increased with increasing light.

The problem of fog in the highlands on aeroponic potato seed production has been investigated, namely the study of adding artificial light using Lighting emitting diode (LED) and florescent lights on the growth and yield of potato seeds in the highlands. Artificial lighting with LED has several advantages, including high efficiency, flexible spectrum and relatively long service life, monochromatic light. The results of the study were that the addition of artificial lights had an effect on the growth of plant height, number of leaves, number of tubers and tuber weight. The addition of artificial light using a red blue LED lamp gave a higher plant height and number of leaves compared to a white fluorescent (neon) lamp at 50 days after planting. The addition of artificial lighting with 18 Watt LED lamps has the potential for higher yields than other types of lamps (Sumarni *et al.*, 2019b). However, from these results, it was still found that some plants had not yet optimal growth. It was suspected that the position of the height of the lamp had an effect on the growth and aeropoonic yields of potato plants. The effect of lamp position on the growth and yield of pakcoy plants hydroponically has been investigated, namely 36 watt LED lamps and 42 watt neon which are placed at a distance of 50 cm from the pakcoy plant causing the tip burn of the leaves of the pakcoy plant (Lindawati, 2015). The impact of providing artificial light through LED lamps and lamp spacing for aeroponic potato seed production in foggy conditions in wet tropical highlands such as Indonesia has not been obtained by scientific information. Therefore, it is necessary to conduct further research on how the influence of the position of the height of the lamp on the growth and yield of aeroponic potato plants. The purpose of this study was to determine the effect of lamp spacing on the addition of artificial lighting on the growth and yield of aeroponic potato seeds in the highlands.

2. MATERIALS AND METHODS

2.1. Experimental Design and Data Analysis

This research was experimental in order to obtain the distance and type of lamp to increase the initiation of potato seed tubers of the Granola variety. The research was conducted from October to December 2018. The electric conductivity of the nutrient solution used was 1.8-2 mS/cm with a pH of 6. The factors tested were:

1. Lamp distance/height (J) with three levels: J1 (110 cm), J2 (120 cm), J3 (130 cm)
2. Lamp (L) with two levels: L1 (LED Red Blue 18 Watt), L2 (NEON White 10 Watt).

Red blue LED lights have 14 Watts of red with a wavelength of 640-680 nm and 4 Watts of blue with a wavelength of 450-470 nm (L1) and 10 Watts of white fluorescent lamps (L2) (Sumarni *et al.*, 2019b), such as in Figure 1. The addition of artificial lighting using LED lights is carried out for 4 hours after sunset (after 17.00 to 21.00). The design used was a completely randomized design (CRD) with three replicates. Parameters of plant growth observed were plant height, number of leaves and plant yield (number of tubers, and tuber weight). Growth observation data and yield were analyzed by F test and continued with Duncan's Double Distance Test (DMRT) level 5%. The research layout is presented in Figure 2.

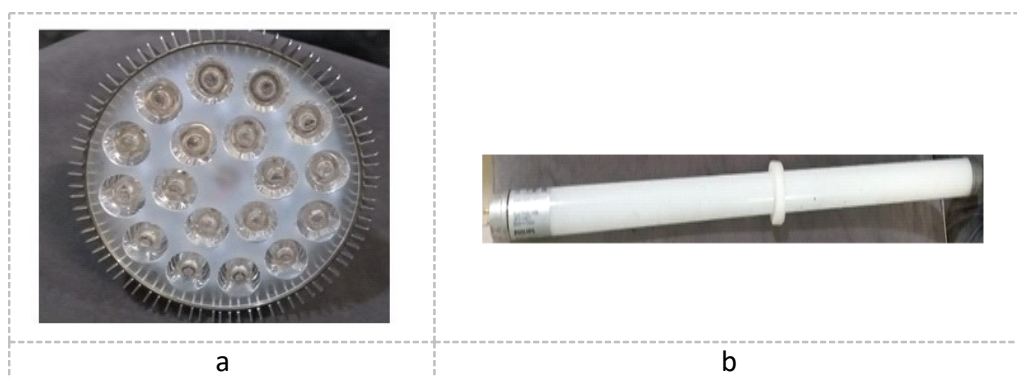


Figure 1. Lamps for plants used in the research (a) red blue LED light lamp, (b) white fluorescent (neon) lamp

3. RESULTS AND DISCUSSION

3.1 Microclimate Inside the Greenhouse

3.1.1 Light Intensity inside the Greenhouse

The growth and development of potato plants is influenced by light intensity. The intensity of light is necessary for the distribution of assimilation and plant development. Each plant requires a different light intensity for growth and development. The intensity of sunlight in the Banjarnegara highlands, Indonesia on average ranges from 2970 to 3250 Lux (Figure 3). The aeroponic potato planting period from October to December in the Banjarnegara highlands has encountered foggy conditions in several days. This condition causes the intensity of sunlight entering the greenhouse low. The results of another study showed that low light intensity (2000-3000 Lux) gave more pronounced stem elongation than higher light intensity. However, to produce larger bulbs, a higher intensity of sunlight is required (> 3000 Lux) (Wahid *et al.*, 2007).

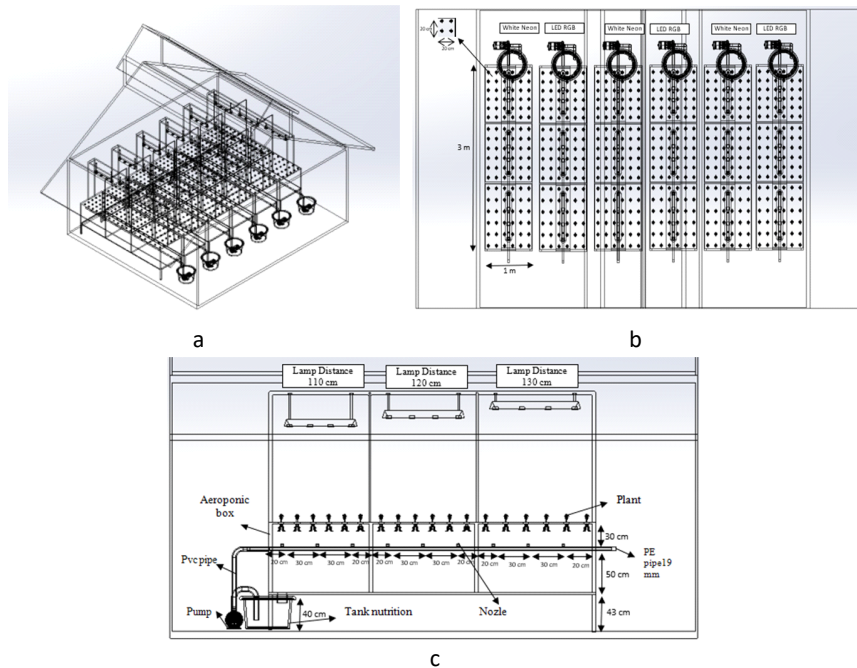


Figure 2. Layout of the placement of lights in the greenhouse (a) schematic in the greenhouse, (b) top view, and (c) aeroponic schemes and lights

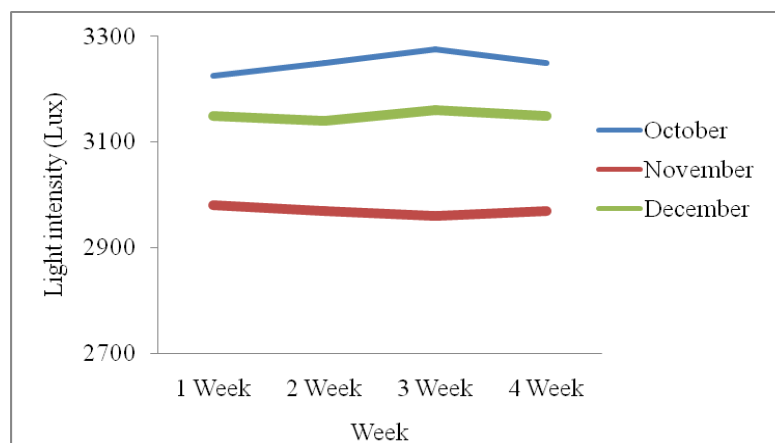


Figure 3. The intensity of sunlight during the research

3.1.2 Air temperature inside the greenhouse

The average air temperature in the greenhouse during this study ranged from 14.5 °C to 15.9 °C (Figure 4). This air temperature is still in the appropriate category for the growth of aeroponic potato plants in the greenhouse. The air temperature in the greenhouse affects the growth and development of aeroponic potato plants. High temperatures generally stimulate stem growth and are unfavorable for leaf and tuber growth at low light intensities. High temperatures can spur potato plants to become bulbous, but the plants are short-lived (quickly die) (Kotak et al., 2007).

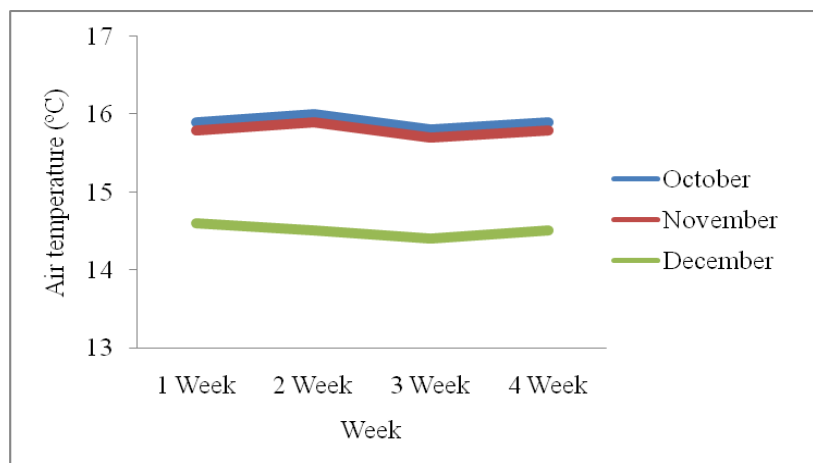


Figure 4. Average air temperature in the greenhouse during growth

3.2. Effect of Light Distance on Plant Growth

3.2.1. Plant Height and Number of Leaves

Provision of artificial light for 4 hours from 17.00 to 21.00 WIB gave different results on the average plant height and different number of leaves at the age of 49 days after planting (DAP) to 56 DAP, as well as for the number of leaves. The combination of lamp type and height also gave different results on the number of tubers and tuber weight of aeroponic potato seeds in the highlands. The addition of lighting with 18 Watt red blue LED lights provides a higher average plant height than 10 Watt white fluorescent lights. The average plant height at 49 DAP using 18 watt red blue LED lamps was 41.4 cm and 69.2 cm, while the white fluorescent lamp was 37.0 cm at 49 DAP and 50.4 cm at 56 DAP. The average number of leaves on the addition of light using 18 watt red blue LED lamps is higher than that on 10 Watt white fluorescent lamps, which is 1656 strands for 18 Watt red blue LED lamps at the age of 49 DST and 223 strands, while for 10 Watt fluorescent lamps an average number of leaves 100.6 leaves at 49 DAP and 110.1 leaves were obtained (Table 1). The appearance of plant height and number of leaves on the use of red blue and white lights is presented in Figure 5.



Figure 5. Appearance of plants using red blue (a) and white (b) LED lights

Table 1. Effect of artificial lighting on plant height and leaf number of potato aeronics

Treatment	Plant height (cm)		Number of leaves (sheet)	
	49 DAP	56 DAP	49 DAP	56 DAP
18 Watt red blue LED lamp	41,4 a	69,2 a	165,6 a	223,0 a
10 Watt white neon light	37,0 b	50,4 b	100,6 b	110,1 b

Note: Numbers which are followed by the same letter are not significantly different in DMRT at the 5% level.

The results above indicate that artificial lighting can be used to help increase the growth of aeroponic potato plants in a greenhouse as a controlled environment (Tian, 2017). Red blue LED lights provide plant height growth and higher number of leaves because red and blue light are more easily absorbed by plants. The combination of red and blue lights also provides an efficient light spectrum for photosynthesis on potato growth in vitro (Hernandez & Kubota, 2016; Hernandez et al., 2016; Fan et al., 2013), but the ratio of red and blue LED lights for each variety is different in different room conditions (Li et al., 2013). Several types of lamps on the market can be seen in Table 2.

Table 2. Several lamps for growing plants (grow light LED) available in the market

No.	Name	Wavelength	Lumen (Lux)	Power
1.	E27 grow light led	Red 630nm blue 460nm		12 Watt
2.	Full spectrum	Red 620-630 nm White light (6000-6500k) Blue fluorescent (460-470 nm) Warm white (3000-3500k) Uv (390-400nm) Infrared light (730-740nm)	6500lm	600-200 Watt
3.	Led plant grow light	460-630 nm		27 Watt
4.	16 Led plant grow light	Red/Blue/UV/IR (630nm:660nm:450nm:460nm:730nm:420nm)	Lumen : 15840 lm	180-1440 Watt
5.	UFO 90W Cree LED Grow Lights	Red/Blue/UV/IR (400nm 460nm 500nm 590nm 605nm 630nm 660nm 730nm 650nm)	11200lux/0.5m 5280lux/1.0m	88-95 Watt

Source: www.kontakledlight.com

Placement of lights at different heights above the surface of aeroponic potato plants gave different results for plant height and number of leaves. Lamps with a height of 110 cm from the surface of the aeroponic box gave a higher average plant height at the age of 49 DAP to 56 DAP compared to the height of the lamps at 120 and 130 cm. The average aeroponic potato plant height at a lamp height of 120 cm and 130 cm gave the same results up to 56 DAP. The average plant height at a lamp height of 110 cm was 42.2 cm for the age of 49 DAP and 64.8 cm at the age of 56 DAP. The average plant height at a height of 120 cm for the age of 49 DAP was 38.2 cm and 60 cm at the age of 56 DAP. The average plant height at a height of 130 cm for the age of 49 DAP was 37.2 cm and 54.6 cm at the age of 56 DAP.

The number of leaves on aeroponic potato plants at a lamp height of 110 cm gave the highest average number of leaves, which was 56.5 leaves (age 49 DAP), compared to a lamp height of 120 cm and 130 cm. Whilst, a lamp height of 120 cm and 130 cm gave similar results, ranging from 45 to 49 strands. However, at 56 DAP the number of leaves of aeroponic potato plants for a height of 110 cm and 120 cm obtained the same results (172 to 175 leaves) and higher than that at the height of 130 cm, which was 152.2 leaves (Table 3). From the results of the position of different lamp heights on the yield of plant height and number of leaves, it was shown that the lamp heights of 110 and 120 cm gave better aeroponic potato vegetative growth and thicker stems than that at the height of 130 cm. The distance of the lamp height of 110 and 120 cm from the top surface of the plant is an appropriate distance to help the growth of leaves. It is presumed that the provision of artificial light during foggy for a distance of 110 and 120 cm is able to provide a higher level of lighting to reach plants than at a distance of 130 cm from the plant surface. This is in accordance with previous research on kailan plants, where the distance of the lamp closer to the leaf surface (20 cm and 40 cm) gives the highest number of leaves and leaf area index compared to the longer distance from the plant surface (60 cm and 80 cm) (Susilowati *et al.*, 2015). Appropriate lighting also supports the growth with stronger stems and greener colors (Lukitasari, 2012).

Table 3. Effect of lamp distance on plant height and number of leaves of aeroponic potato

Treatment	Plant height (cm)		Number of leaves (sheet)	
	49 DAP	56 DAP	49 DAP	56 DAP
Distance 110 cm	42.2 a	64.8 a	56.5 a	175.3 a
Distance 120 cm	38.2 b	60.0 b	49.0 b	172.2 a
Distance 130 cm	37.2 b	54.5 b	45.2 b	152.2 b

Note: Numbers followed by the same letter are not significantly different in DMRT at the 5% level.

3.2.2. Number of Bulbs and Bulb Weight

The number of bulbs and bulb weight gave significant results from the interaction effect of the treatment combination between the type of lamp and the height of the lamp position. The combination of RB LED lamps with a height of 110 cm provides the highest number of bulbs compared to RB LED lamps of 120 cm, 130 cm and white lamps in the form of neon. RB LED lamps with a height of 130 cm and white lamp of 110 cm and 130 cm gave the lowest number of bulbs (13 to 19.7 plants). The weight of aeroponic potato seed tubers in the highest highlands was obtained from a combination of RB lamps with a height of 110 cm, which was 29.3 grams of tuber, and the lowest was from an RB LED lamp with a height of 130 cm and white lamp lights with various heights, which was 11.7 to 19.5 grams per tuber (Table 4).

The results of this study are in accordance with the of previous studies, where addition of red and blue LED lights simultaneously provide optimal growth of potato plantlets compared to those of alternately given red and blue lights (Jao, 2004; Chen *et al.*, 2018). In plant tissues like stems and leaves, the synthesis of secondary metabolites can change due to physiological, biochemical, and genetic factors in which light is one of the photoreceptors (Lefsrud *et al.*, 2008). About 90% of the light in the red and blue spectrum is absorbed by photosynthetic pigments (Terashima *et al.*, 2009).

Table 4. The interaction effect of artificial lighting distance on plant height on the number and weight of tubers

Treatment	Number of bulbs per plant (tuber)	Bulb weight per tuber (gram)
RB LED Lights, 110 cm	31,7 a	29,3 a
RB LED Lights, 120 cm	20,0 b	23,7 b
RB LED Lights, 130 cm	13,7 c	19,5 c
White neon light, 110 cm	13,0 c	18,0 c
White neon light, 120 cm	22,7 b	11,7 c
White neon light, 130 cm	19,7 c	19,0 c

Note: Numbers which are followed by the same letter are not significantly different in DMRT at the 5% level.

Thus, the rate of photosynthesis, plant physiology and growth, development is significantly affected by blue or red light (Chen *et al.*, 2014). Potato tuber initiation is a complex and complicated process because it is controlled by many factors. The plant hormone, gibberellic acid (GA), is a key hormone influencing potato tuber initiation (Roumeliotis *et al.*, 2012). The light spectrum can be used to induce and develop mini tubers by regulating hormone concentrations, especially GA. The development of miniature bulbs requires a range of wavelengths in the light spectrum. The greatest development of mini bulbs was found in the combined spectrum of red and blue LEDs (Teo *et al.*, 2017). Therefore, LEDs are a potential source of artificial light as well as artificial light for aeroponic potato seed production in the highlands during foggy conditions.

In this study, 4 hours of light were added, so that the total lighting time was 16 hours for normal conditions without cloudy days. The results of previous studies on tomato production with the addition of artificial light showed that, tomato plant leaf developed chlorosis after 7 weeks, tomato plants for 5 to 7 weeks planted under continuous natural light had better growth and higher yields than those for light additions of 14 hours and 17 hours for cucumber and tomato plants. Therefore, it is recommended that the application of artificial lighting be carried out by considering the photoperiod of the vegetative and generative periods of plants (Demers *et al.*, 1998; Menard *et al.*, 2006; Dorais, 2003).

4. CONCLUSIONS AND RECOMMENDATIONS

Height and type of lamp gave different results on the average plant height and number of leaves. The combination of plant height and lamp type gave different results on the number of tubers and tuber weight of aeroponic potato seeds in the highlands. Combination of RB LED lamps with a height of 110 cm gave the highest number of tubers (31.7 bulbs) compared to RB LED lamps of 120 cm, 130 cm and white florescent lamps. RB LED lamps with a height of 130 cm, white lamps 110 cm and 130 cm gave the lowest number of bulbs of 13 to 19.7 per plant. The highest yield of aeroponic potato seed tubers in the highlands was obtained from a combination of RB lamps with a height of 110 cm, which was 29.3 grams of tubers. The lowest bulb weights of RB LED lamps are from 130 cm high and white lamps with various heights, which are 11.7 to 19.5 grams per bulb.

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