LIGHTING DURATIONS AND COLOR EFFECTS TO THE DIFFERENT POTATO CULTIVARS GROWTH RESPONSE AND MINI TUBERS FORMATION IN AEROPONIC SYSTEM

Erny Ishartati, Sukardi, Aniek Iriany, Rudy Madiyanto, Devi Dwi Siskawardani

University of Muhammadiyah Malang, Raya Tlogomas Road 246 Malang City (65144) Indonesia

Abstract

Potato (Solanum tuberosum L.*) plays an important role on food diversification. But Indonesia Agriculture Ministry reported that the potato seed availability always be deficient. Therefore, it needs to develop the superior seed production technic. This study aimed to analyze the effect of lighting duration and lighting color to the potato tubers formation (Granola cv., and PPT4-Zebra cv.) in aeroponic system. Randomized Complete Block Design (RCBD) Factorial with 3 factors and 4 replications were applied. The first factor was lighting duration (L), the second was lighting color (W), and the last one was potato cultivar (V). The results showed that lighting duration, lighting color and potato cultivar significantly affect to the plant height, leaves number, stem diameter, root length, chlorophyll content, tuber number and diameter separately. There was insignificant interaction between lighting duration, lighting color and potato cultivar to the tuber weight. PPT4-Zebra cultivars expressed plant growth and tuber yield were better than Granola cultivars.*

Key words: *potato, lighting durations, lighting color, aeroponic system*

1. INTRODUCTION

The concern of efficiency energy application, environmental impact and food safety in agricultural production is growing (Pinho *et al*., 2012). Aeroponics uses soilless system and nutrients management well. The formulated nutrient solution is used in this system, so there is no fertilizer which is wasted and leached. The increasing harvest production in aeroponic systems can be supported by light spectrum color levels and lighting durations. The light spectrum can be manipulated used by the lamp or LED. The different color of spectrum will affect the crops growth, every color of spectrum has their own wavelength which able to be absorbed by crops (Ermawati, Indradewa, and Trusnowati, 2012).

Potato (*Solanum tuberosum* L.) is a vegetable commodity which has high economic potential and plays an important role on functional food and food diversification as well. BPS-Indonesia, (2014) reported that potato consumption in Indonesia was 1.027.845 ton/ years, while the potato production about 1.004.041 ton/years. Therefore Indonesia had to import potato to accomplish the requirement (Balitsa, 2015; Agriculture Ministry, 2015). Potato production needs to enhance which will be followed by seeds request (G0, G1, G2, G3 and G4) on breeding or field consumptions. The limited great seeds (uncertified seeds) which grown was the main rationale of low potato production (Hidayat, 2011; Daiana *et al*., 2013).

Agriculture Ministry of Indonesia showed that in 2008, potato seeds requirement was about 8% (requirement was 103.272 ton, but the availability was 8.066 ton), in 2009 was about 13% (requirement was 103.375 ton and availability was 13.481 ton), in 2010 was about 14% (requirement was 103.478 ton and availability was 14.702 ton), and in 2011 was about 15% (requirement was 103.582 ton and availability was 15.537 ton). A big seeds providing obstacle not only quantity but also quality. So that, it needs to create the superior seed production technic, because potato seeds which produced conventionally is not guarantee will be free from pathogen.

Potato which be produced in aeroponic systems by nutrients depletion at the roots, well developed in Indonesia. Suryono and Dewi (2012); Farran and Mingo-Castel (2006) stated that aeroponic system has superiority on the quantity potato tubers production (potato could produce 3-5 tubers/crop conventionally), healthy tubers, reducing pesticides, pathogen free, easy for harvesting and nutrient control. Tubers production in aeroponic system are about 16-29 tubers/crop (Muhibuddin *et al*., 2009).

This study aimed to analyze the effect of lighting duration, lighting color, and potato cultivars (Granola cv., and PPT4-Zebra cv.) to the tubers production in aeroponic systems.

2. METHODS

The research was conducted at Jurangkuali Sumber Brantas villages, in Batu City. The location was 1700 mdpl, rainfall 2500 mm/year, and temperature 12 ^{0}C – 22 ^{0}C. Potato cv. Granola and PPT4-Zebra were grown, while disinfectants, cocopeat, rooton F and nutrients were applied for aeroponic. Tray, seed box, glove, scalpels blade, hand sprayer, petri dish, mulch, styrofoam, sponge, paranet, lamp (yellow, green, purple), strapless, tweezers, aeroponic tub sets, hoses, nozzles, thermometer, scales, analytical scales, rulers, caliper, camera and stationery were used for this research.

Randomized complete block design factorial (RCBD factorial) with 3 factors and 4 replications (each consisted 8 samples) were applied. The first factor was the lighting duration (L) which consisted L1 (15 hours) and L2 (17 hours). The second was lighting color (W) which composed W1 (white), W2 (purple), and W3 (yellow). The last factor was cultivar (V) that consisted V1 (Granola) and V2 (PPT4-Zebra). The variables were plant height, leaves number, stem diameter, root length, chlorophyll content, tuber number, diameter and weight. The data were analyzed using Analysis of Variance (ANOVA) and followed by LSD test 5%.

Research implementations were consisted of 4 steps:

2.1 Aeroponic Installation Preparation

Aeroponic bucket was cleaned using water, then it was sterilized using clorox 5% for 3 days to prevent the bacterial and fungal contamination. After 3 days the bucket was rinsed again using water to remove the clorox. Afterwards, the bucket was covered using styrofoam and mulch. Some holes were made for planting the tubers. The nutrients reservoir was built and misting time was arranged too. The timer was activated every 10 minutes for 5 minutes misting. The nozzle, faucet, and residual pipes were checked, then LED lamps (yellow, white, and purple), paranet and dividers were installed.

2.2 Planting Preparation

Rooton F was given to stimulate potato root growth in tray where cocopeat was applied as medium of planting up to 14 days. After the roots appeared, potato seed was transplanted at seed box containing cocopeat for 14 days. Then it was ready placed at aeroponic bucket. The potatoes which has root grown were cut to 8 cm, then fungicide were sprayed to prevent diseases. The last one, potato were inserted into styrofoam holes.

2.3 Nutrient Management

Mix nutrition AB contained of macro and micro nutrients, were given for hydroponics. The nutrient elements were consisted of N (Nitrogen), P (Phosphor), K (Potassium), Ca (Calcium), Mg (Magnesium), S (Sulfur), Fe (Iron), Mn (Manganese), Cu (Cuprum), Zn (Zinc), B (Boron), and Mo (Molybdenum). These nutrient elements were dissolved in a nutritional stank and sprayed for 5 minutes at 10 minute intervals.

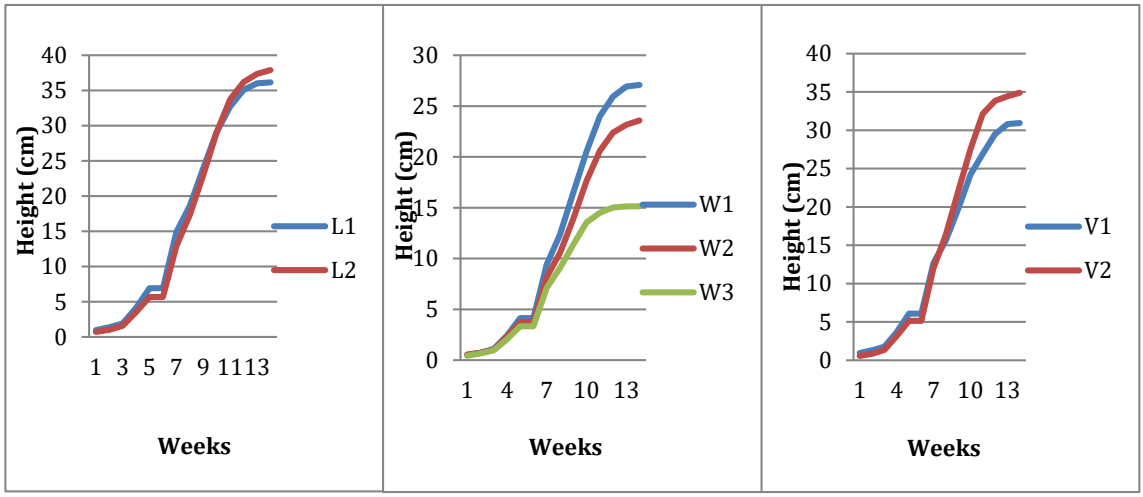
2.4 Maintenance

This steps included nozzle and temperatures checking, filters and styrofoam cleaning, then pest and disease control used fungicides and pesticides every three days. The maintenance process was very important to get the sterilized potato.

3. RESULTS AND DISCUSSION

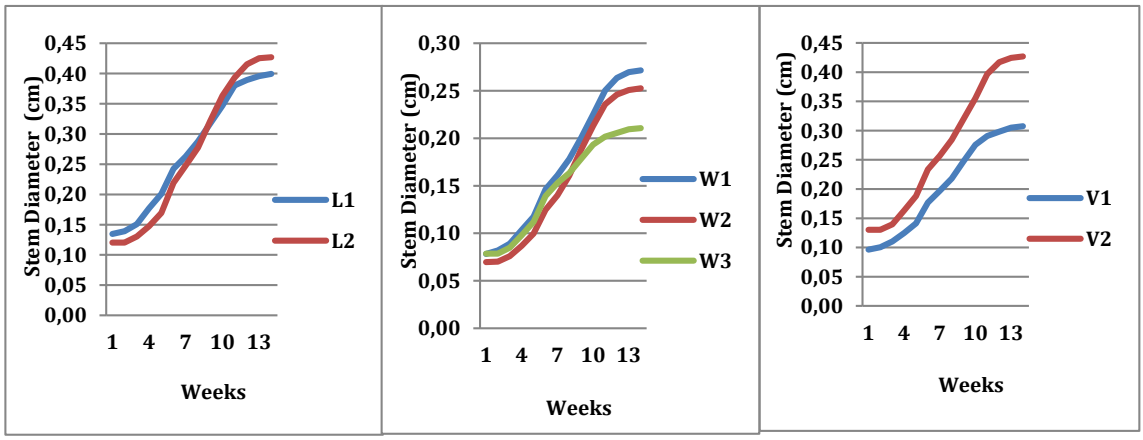
Lighting duration, lighting color and potato cultivar showed gave significantly effect on the plant height at 11st - 14th weeks; stem diameter at 1st - 14th weeks; leaves numbers at 1st, 2nd, 9th - 14th weeks; root length at 4th, 6th, and 8th; chlorophyll contents 6th, 9th, 11st and 14th weeks; then tuber number and

diameter. Generally, the treatments combination gave significantly effect to the all vegetative and generative variables except tuber weight at the end of observation.



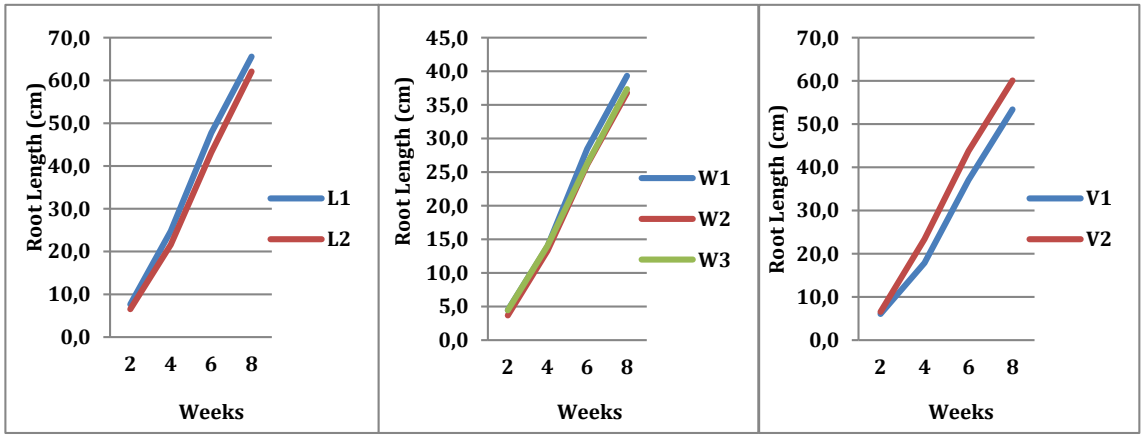
Graph 1. Potato height development (cm) in lighting durations (L), lighting color (W), and potato cultivar (V) treatments at 1st – 14th weeks after transplanting.

Graph 1 showed the potato height development in all treatments separately. The lighting durations gave similar response at every weeks, furthermore it described that linier trend between potato height and lighting duration. White light tend to be better than purple and yellow lights at 9th – 14th weeks for potato height. PPT4 - Zebra cultivars indicated cellular elongation response tend to be higher compared to Granola cultivars.

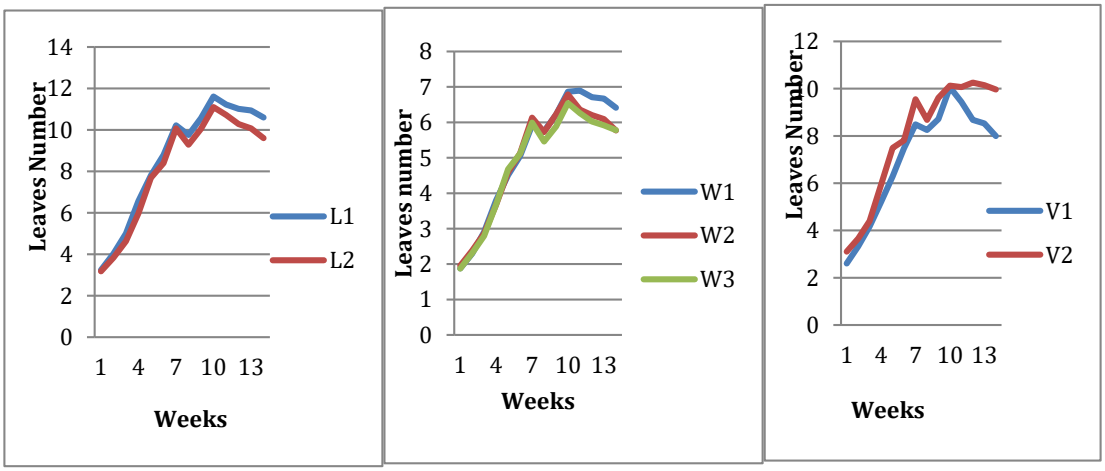


Graph 2. Potato stem diameter (cm) in lighting durations, lighting color, and potato cultivar treatments at 1st – 14th weeks after transplanting.

The trend of stem diameter growth was same as potato height. The lighting duration gave insignificant difference response on potato stem diameter (Graph 2). However, white light performance was the best treatment compared to purple and yellow lights at 10th – 14th weeks. PPT4-Zebra cultivar tend to be better stem diameter growth than Granola cultivars.



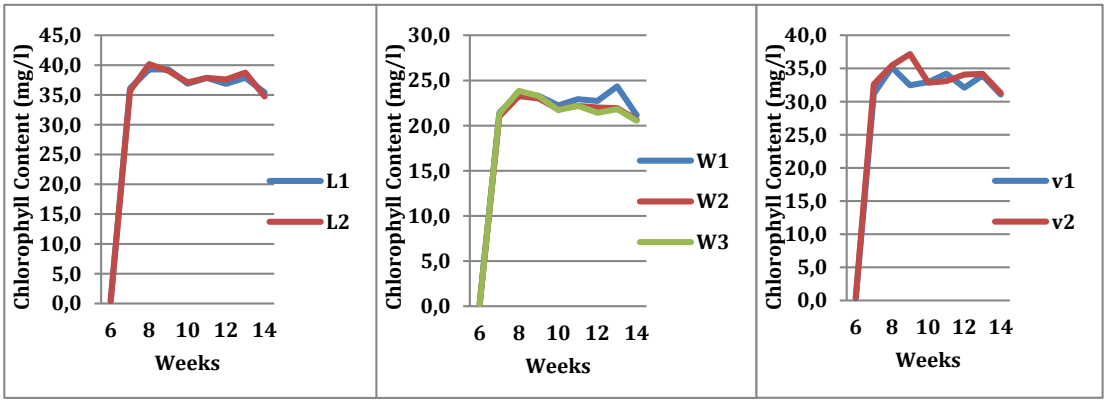
Graph 3. Root length (cm) in lighting durations, lighting color, and potato cultivar treatments at 1st – 14th weeks after transplanting.



Graph 4. Leaves numbers in lighting durations, lighting color, and potato cultivar treatments at 1st – 14th weeks after transplanting

The leaves number of potato trend increased at 1st – 7th weeks but decreased at 7th – 8th weeks for all treatment (Graph 4). Potato leaves numbers at lighting duration gave similarly responded, and 15 hours lighting was the highest number. White light gave the best effect compared to purple and yellow lights which were insignificant difference. PPT4-Zebra cultivars showed the best response compared to Granola cultivars at 9th – 14th weeks.

The wavelength of spectrum will impress the wide of stomata in photosynthetic process and for reaching the optimum height (vegetative phase) before flowering phase (Wiguna and Nada, 2014). The lighting time also showed able to increase the growth and quantity potato tubers. Generally, it can express that the intensively lighting sun duration will improve the photosynthesis, so the production will be better (Sutoyo, 2011).



Graph 5. Chlorophyll content (mg/l) in lighting durations, lighting color, and potato cultivar treatments at 1st – 14th weeks after transplanting.

The chlorophyll content progression of potato leaf was insignificant difference between lighting duration, light color and cultivar (Graph 5). In the rules of light absorption by plants Salisbury & Ross (1991) described that the chlorophyl a optimally absorbs light at the blue-green spectrum and chlorophyll b absorbs light in the yellow-green spectrum (500-600 nm). The most of plant leaves absorb more than 90% of the purple and blue wavelengths almost as much as the percentage of orange and red wavelengths. Both chlorophyll absorbs strongly the purple, blue, orange and red wavelengths. The results showed that white light gave better growth followed purple and yellow respectively.

The white light is a collection of different types of color spectrum (rainbow). Plants use almost all the color spectrum that exists, even though blue and red were the most (Mass, Kim, Wheeler, & Mitchell, 2008; Fraszczak, 2013). Samuolienė *et al*. (2010) revealed that plants which grown under the white spectrum are better when compared to various colors, although the tubers weight were greater at purple.

Table 1. The Tuber Number and Diameter in Lighting Durations, Lighting Color, and Potato Cultivar

Treatments			Tuber Number		Tuber Diameter (cm)	
15 hours	White	Granola	2.973	c	1.314	bcde
15 hours	White	PPT4 Zebra	5.656	bc	2.357	a
15 hours	Purple	Granola	4.175	bc	1.146	e
15 hours	Purple	PPT4 Zebra	6.594	bc	2.015	abc
15 hours	Yellow	Granola	9.813	ab	1.115	e
15 hours	Yellow	PPT4 Zebra	5.786	bc	1.888	abcd
17 hours	White	Granola	3.076	c	1.288	cde
17 hours	White	PPT4 Zebra	5.125	bc	2.032	ab
17 hours	Purple	Granola	3.353	c	1.515	bcde
17 hours	Purple	PPT4 Zebra	12.643	a	1.789	abcde
17 hours	Yellow	Granola	9.219	ab	1.262	de
17 hours	Yellow	PPT4 Zebra	13.960	a	1.636	abcde

Note: *Significantly different ($p \leq 0.05$); the number which followed the same alphabet was insignificant

Table 1 revealed that the highest tuber number was obtained by combination of 17-hours lighting duration and yellow light treatment, both at the PPT4-Zebra and Granola cultivars. The largest tuber diameter was obtained at the PPT4-Zebra cultivar, at white or yellow light and in 15 or 17 hours. Then the tuber weight observation did not show significantly different results (Table 2).

Light is an important energy source which affects plant life both in terms of photosynthetic speed and assimilation accumulation, then plays an important role in plant growth and development. However, excessive lighting has a negative impact on potatoes growth. Potatoes which grown in 24-hour long exposure had 33% lower of photosynthesis rate than those that grown in 12 hours of exposure. The decreasing photosynthesis rate associated with starch accumulation in leaves, which caused by greater increasing photosynthesis production than photosynthesis storage.

Table 2. The Tuber Weight in Lighting Durations, Lighting Color, and Potato Cultivar treatments.

Treatment	Tuber weight	
Lighting duration		
15 hours	66.092	a
17 hours	29.508	a
Lighting color		
White	23.816	a
Purple	89.682	a
Yellow	29.903	a
Cultivar		
Granola	8.319	a
PPT4 Zebra	87.281	a

Note: *Significantly different ($p \leq 0.05$); the number which followed same alphabet showed not significant

The damage crops symptoms had been seen too in potato when excessive exposure (Sysoeva, Markovskaya, & Shibaeva, 2010). Hidayat (2011) used 16 hours of exposure that equivalent to 2.400 Luks in seed yield production (G0). Based on the data, the light duration of 15 and 17 hours did not give different response to the all vegetative variables when viewed separately without combination. Short days were needed to stimulate tuber formation, while long days for top plants growth. Therefore tuber formation became late 3 to 5 weeks compared to short days. Darkness and light penetration minimization were required in tuber formation (Chang *et al*., 2011; Chang *et al*., 2012). Excess light process will encourage shorter tuber growth compared to the appropriate lighting (Mbiyu & Muthoni, 2013; Ndondji, 2014).

4. CONCLUSION

Lighting duration, lighting color and potato cultivar significantly influenced the plant height, leaves number, stem diameter, root length, chlorophyll content, tuber number and diameter. There is insignificant interaction between lighting duration, lighting color and potato cultivar to the tuber weight. PPT4-Zebra cultivars showed better plant growth and tuber yield compared to Granola cultivars in various combinations of lighting duration and lighting color.

REFERENCES

Balai Penelitian Tanaman Sayuran. 2014. Untuk Kualitas Kentang Terbaik. Lembang <http://balitsa.litbang.pertanian.go.id/ind/index.php/berita-terbaru/272-untuk-kualitas-kentang-terbaik.html> accessed 06 April 2016.

Chang D.C., Cho L.C., Suh J.-T., Kim S.J., Lee Y.B. (2011): Growth and yield response of three aeroponically grown potato cultivars (Solanum tuberosumL.) to different electrical conductivities of nutrient solution. American Journal of Potato Research, 88: 450–458.

Chang D.C., Park C.S., Kim S.Y., Lee Y.B. (2012): Growth and tuberization of hydroponically grown potatoes. Potato Research, 55: 69–81.

Dianawati, M., Ilyas, S., Watimena, G.A, & Susila, AD., (2013). Minituber Production of Potato Aeroponically by Determining Optimum Rate of Nitrogen Foliar Fertilizer. J. Hort, 23(1), 47–55.

Ermawati, D., Indradewa, D., & Trusnowati, S. (2012). Pengaruh Warna Cahaya Tambahan Terhadap Pertumbuhan dan Pembungaan Tiga Varietas Tanaman Krisan (Chrysanthemum morifolium) Potong. Vegetalika, 1(3), 31–42.

Farran I., Mingo-Castel A.M. (2006): Potato minituber production using aeroponics: Effects of plant density and harvesting intervals. American Journal of Potato Research, 83: 47–53.

Fraszczak B., 2013. Effect of short-term exposure to red and blue light on dill plants growth. Hort. Sci. (Prague), 40: 177–185.

Folta, K.M. Folta and S. A. Maruhnich, 2007, Green light: a signal to slow down or stop, J Exp Bot (2007) 58 (12): 3099-3111.

Hidayat, I. (2011). Produksi Benih Sumber (G0) Beberapa Varietas Kentang dari Umbi Mikro. J. Hort, 21(3), 197–205.

Kementrian Pertanian. 2015. Buletin Triwulan Ekspor Komoditas Pertanian. Pusat Data Sistem Informasi Pertanian, Kementrian Pertanian Republik Indonesia. Vol VII No (1).

Massa, G. D., Kim, H. H., Wheeler, R. M., & Mitchell, C. A. (2008). Plant productivity in response to LED lighting. HortScience, 43(7), 1951–1956.

Mbiyu, M., & Muthoni, J. (2013). Use of aeroponics technique for potato (Solanum tuberosum) minitubers production in Kenya. International Journal of Horticulture and Floriculture, 1(3), 16–20. <http://www.internationalscholarsjournals.org/journal/ijhf/articles/application-buy-vision>

Muhibuddin, Zakaria, AB, Lisan, E & Baharuddin 2009, 'Peningkatan produksi dan mutu benih kentang hasil kultur in-vitro melalui introduksi sistem aeroponik dengan formulasi NPK', Prosiding Seminar Nasional Pekan Kentang 2008, Puslitbang Hortikultura, Badan Litbang Pertanian, Kementerian Pertanian, Jakarta, no. 1, hlm. 102-10.

Pinho, P., K. Jokinen and L.Halonen. 2012. Horticultural Lighting—Present and Future Challenges, Lighting Research and Technology. 44(4) 2012, pp. 427-437. doi:10.1177/1477153511424986

Rykaczewska, K. (2016). The potato minituber production from microtubers in aeroponic culture. Plant, Soil and Environment, 62(5), 210–214. <http://doi.org/10.17221/686/2015-PSE>

Samuolienė, G., A. Brazaitytė, A. Urbonavičiūtė, G. Šabajevienė, and P. Duchovskis , 2010, The effect of red and blue light component on the growth and development of frigo strawberries, Zemdirbyste-Agriculture, vol. 97, No. 2 (2010), p. 99–104

Salisbury, F., & Ross, C. (1991). Plant Physiology, Wadsworth Publishing Company

Suryono, A., & Dewi, R. S. (2012). Budi Daya Kentang dengan Teknologi Aeroponik. Suara Merdeka, p. 19. Jawa tengah.

Sutoyo. 2011. Fotoperiode dan Pembungaan Tanaman. Jurnal Buana Sains. Vol 11(2) :137-144.

Sysoeva, M., Markovskaya, E., & Shibaeva, T. (2010). Plants under continuous light: a review. Plant Stress. 4(1): 5–17. Retrieved from <http://www.globalsciencebooks.info/Online/GSBOnline/images/2010/PS_4(1)/PS_4(1)5-17o.pdf>

Tshisola Steve Ndondji. (2014). Improved potato (Solanum tuberosum) seed production through aeroponics. Stellenbosch University.

Terashima I, Fujita T, Inoue T, Chow WS, Oguchi R (2009) Green light drives leaf photosynthesis more efficiently than red light in strong white light: revisiting the enigmatic question of why leaves are green. Plant Cell Physiol 50: 684–697