Vol. 11, No. 2 (2022) : 184 - 194 DOI : http://dx.doi.org/10.23960/jtep-l.v11i2.184-194

Agricultural Engineering
UNIVERSITY OF LAMPUNG

JURNAL TEKNIK PERTANIAN LAMPUNG

ISSN 2302-559X (print) / 2549-0818 (online)
Journal homepage : https://jurnal.fp.unila.ac.id/index.php/JTP

Application of Electrical Conductivity (EC) for Some Potato Varieties in the Aeroponically Seed Production with Root Zone Cooling and Evaporative Cooling in Tropical Lowlands

Eni Sumarni[1]✉, Priswanto[2], Zaroh Irayani[3]

[1]Department of Agricultural Technology, Faculty of Agriculture, Jenderal Soedirman University. Purwokerto, INDONESIA.
[2]Electrical Engineering Department, Faculty of Engineering, Jenderal Soedirman University. Purbalingga, INDONESIA.
[3]Physics Study Program, Fakulty of Mathematic and Natural Sciences, Jenderal Soedirman University. Purwokerto, INDONESIA.

Article History :

Received : 231 January 2022
Received in revised form : 2 March 2022
Accepted : 9 May 2022

Keywords :
Cultivation,
Greenhouse,
Hydroponics,
Nutrition,
Tubers

✉Corresponding Author:
eni.sumarni@unsoed.ac.id

ABSTRACT

Aeroponic potato seed production in the lowlands has been carried out by root zone cooling and evaporative cooling in order to reduce high temperature stress for the roots and tops of potato plants. However, the effect of nutrient solution EC on several varieties of potato seeds for an aeroponic system with a combination of root zone cooling and evaporative cooling for potato seed production in the lowlands has not been done. This study aims to obtain the response of potato varieties and the application of different ECs on aeroponic seed production with root zone and evaporative cooling in tropical lowlands. The factors analyzed : 1. Variety (V): V1 (MZ), V2 (Granola K), V3 (Granola L), and 2. Nutrient concentration (EC): EC1 (1.5 mS/cm for Week 1- 4, 2 mS/cm for Week 5 until harvest), and EC2 (1.5 mS/cm for Week 1-4, and 3 mS/cm for Week 5 until harvest), while the design used was RAK with 3 replications. The results showed that the Granola K and EC2 varieties are more efficient for potato seed production in the lowlands with the application of root zone and evaporative cooling. This variety produced the highest number of tubers up to 30 tubers/plant. Similarly, the Granola L and MZ varieties showed similar results with a total number of tubers above 10 tubers/plant.

1. INTRODUCTION

Potato is one of the potential commodities for local food fulfillment and world food security (Gastelo *et al.*, 2014; FAO, 2011). Potato tubers contain energy, vitamins and minerals needed by the body (Beals, 2019). This makes potatoes a commercial tuber crop and is consumed almost every day by people around the world (Lutaladio *et al.*, 2009). Indonesia is one of the countries that produces potatoes to meet the needs of seeds and also the consumption of its people. However, potato productivity is still fluctuating, so potato imports are still increasing every year (BPS, 2014).

The problem of fluctuating potato productivity is caused by the condition of seed availability. Quality potato seeds have problems with continuity and increase in production. The need for potato seeds in Indonesia reaches 96.77 tons while the availability of certified seeds in the country is only 8,066 tons (8.3%) (Directorate General of Horticulture, 2010). To date, the fulfillment of the need for certified potato seeds has only reached 10% (Mulyono *et al*., 2017; Balai Penelitian Tanaman dan Sayuran, 2016; 2017). Meanwhile, potato seeds used by farmers are currently experiencing a decline in quality, because in potato planting centers endemic bacteria and viruses that damage potato crops (Sayaka & Hestina, 2011). In addition, potato plants in the highlands are on a steep slope, which reaches >30% and has a high erosion impact (Henny *et al*., 2011). This potato production center in the highlands of Indonesia has recently experienced extreme weather, namely the fall in frost which has resulted in the destruction of potato crops in open fields.

From these conditions, the development of potato planting in the lowlands has become an effort to increase potato seed production (Sumarni *et al*., 2013a). The technology for producing high, healthy and continuous potato seeds has been produced through aeroponic technology (Otazu, 2010) and as an effort to shorten the seedling cycle (Dianawati & Wattimena, 2014). Aeroponic potato seed production in the lowlands has been carried out by modifying the root area in order to reduce high temperature stress, namely by root zone cooling carried out at an altitude of 250 m above sea level and 115 m above sea level successfully obtained tubers (Sumarni *et al*., 2013abc; Sumarni *et al*., 2016; Sumarni *et al*., 2018). Control of air temperature at the top of the plant by evaporative cooling to reduce the percentage of burned plants has also been carried out, the result can reduce the percentage of burned leaves and potentially increase tuber yields (Sumarni *et al*., 2021). Aeroponics technology as a cultivation technology to increase potato seed production has become a new spirit in the context of potato seed self-sufficiency.

One of the factors supporting the success of aeroponic cultivation technology is the electrical conductivity of nutrient solution (EC). The EC reflects the total ions contained in the nutrient solution. The EC concentration of the nutrient solution affects the absorption of nutrients by plants so that it has an impact on the yield and quality of tubers (Chang *et al*., 2011). Potato plants are one of the plants that are sensitive to EC. Application of EC nutrient solution that is not suitable for the stage of plant growth, can be toxic to plants (Teixeira & Pereira, 2007). The results of the study on the impact of providing nutrient solution EC that were not adjusted to the growth stage and yield of potato tubers on the soil caused stunted plant growth, reduced tuber yield and changes occurred in the dry content of substances, soluble solids and secondary metabolites in tubers (Levy & Veilleux, 2007). High EC concentrations of nutrient solution cause water deficit in plants due to reduced osmotic potential of nutrient solution, greater availability of ions in nutrient solution or excessive uptake of ions (Greenway & Munns, 1980).

The effect of electrical conductivity (EC) for nutrient solution on aeroponic potato seed production by application of cooling to tropical lowland root zones, Indonesia has been carried out. The results of the study were that the EC nutrient solution with a concentration of 1 mS/cm at the age of 1-3 weeks after planting and 3 mS/cm at 4 weeks before harvest produced the highest number of tubers compared to EC 4 mS/cm and EC 6 mS/cm on the use of seeds from cuttings 1 and 2 (Sumarni *et al*., 2019). However, how the effect of nutrient solution EC on several potato seed varieties used for aeroponic systems with a combination of root zone cooling and evaporative cooling controls for potato seed production in the lowlands is not yet known. This is important to do to obtain complete scientific information on the use of varieties in order to produce a high number of tubers in the system. The purpose of this study was to obtain the response of potato varieties and the application of different EC on aeroponic seed production with root zone cooling and evaporative cooling control applications in tropical lowlands.

2. MATERIALS AND METHODS

The research was conducted in the greenhouse of the Faculty of Agriculture. General Sudirman University. Purwokerto, Central Java at an altitude of ±115 m above sea level. The research was carried out from May to September 2021. The greenhouse used was a semi-cylindrical type with dimensions of 20 m long, 12 m wide and 2.5 m high. The greenhouse in this study only uses natural ventilation on its walls.

2.1. Root Zone Cooling Application

The root zone cooling application was carried out by cooling the root area of potato plants grown aeroponic in a greenhouse. The cooling process is carried out by spraying a cold nutrient solution with a temperature of 10 °C. Nutrient solutions are administered using an automatic timer. The construction and workings of an aeroponic system with root zone cooling have been used in previous studies to obtain the appropriate root zone cooling temperature. High pressure pump is used to deliver nutrients through nozzles to plant roots. The timer is used to control the nutrient spraying time, the chiller is used to cool the nutrients, and the submersible pump is to flow the nutrients to be cooled into the chiller. The layout of the aeroponic system is presented in Figure 1 (Sumarni *et al*., 2013a; Sumarni *et al*., 2019).

The evaporative cooling application used in this study is a modification of the direct evaporative cooling method in the previous study (Sumarni *et al*., 2021) with the modifications made, namely changing the distance of the Collnet placement. Collnet used has a capacity of 22 liters per hour (Figure 2). In this study, the aeroponic chamber used was 1.0 m (length) × 1 m (width) × 0.5 m (height). The outer aeroponic chamber is made of 12 mm thick multiplex wood, the inside is insulated with 2 cm thick styrofoam. Styrofoam as a place to plant using a thickness of 3 cm. Planting distance of 15 cm × 15 cm, so that in one aeroponic container there are 36 plants.

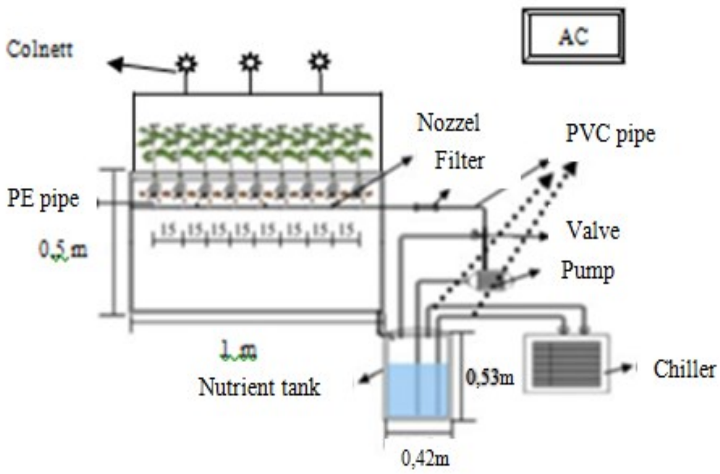

Figure 1. Schematic of aeroponics with root zone cooling and evaporative cooling (Sumarni *et al*., 2013a; Sumarni *et al*., 2021)

The evaporative cooling application used in this study is a modification of the direct evaporative cooling method in the previous study (Sumarni *et al*., 2021) with the modifications made, namely changing the distance of the Collnet placement. Collnet used has a capacity of 22 liters per hour (Figure 2). In this study, the aeroponic chamber used was 1.0 m (length) × 1 m (width) × 0.5 m (height). The outer aeroponic chamber is made of 12 mm thick multiplex wood, the inside is insulated with 2 cm thick styrofoam. Styrofoam as a place to plant using a thickness of 3 cm. Planting distance of 15 cm × 15 cm, so that in one aeroponic container there are 36 plants.

Figure 2. Types of Colnet used in this study

2.2. Experimental Design and Data Analysis

The root zone cooling temperature used is 10°C. Two factors implemented include:

1. Varieties (V): V1 (MZ), V2 (Granola K), V3 (Granola L)
2. Nutrient concentration (EC): EC1 (1.5 mS/cm week 1-4, 2 mS/cm week 5 until harvest), EC2 (1.5 mS/cm week 1-4, 3 mS/cm week 5 until harvest)

The plant growth parameters observed included: plant height, number of leaves and plant yields (number of tubers, tuber size). The design used was RAK with 3 replications. Growth observation data and yield were also analyzed by F test and continued with Duncan's Double Distance Test (UJGD) at 5% level.

3. RESULTS AND DISCUSSION

3.1. Microclimate in the Greenhouse

The average air temperature in the greenhouse during the growth of potato plants is 30.75 °C and humidity is 76.2%. The maximum temperature during the day reaches 36.6 °C (Figure 3). The air temperature in the greenhouse without microclimate modification indicates that the conditions are not optimal for potato seed production in the lowlands. Potato plants require an average temperature of 20-25 °C for optimal tuber initiation. The average nighttime temperature ranges from 18-20 °C (Levy & Veilleux, 2007).

The air temperature in the lowland greenhouse that is not yet optimal is controlled by the application of root zone cooling, which is limited cooling in the root area with a temperature of 10 °C. The results of this control resulted in air temperature conditions in the root area of 13.5 °C to 14.7 °C so that it was optimal for potato tuber initiation in the lowlands (Figure 4). Air temperatures below 20 °C can accelerate tuber initiation compared to temperatures above 20 °C (Ewing & Struik, 1992). The application of root zone cooling has been successfully used to help create low air temperatures in the root areas of potato plants at high temperature conditions in the lowlands to produce potato seeds (Sumarni *et al*., 2013; 2019, 2021).

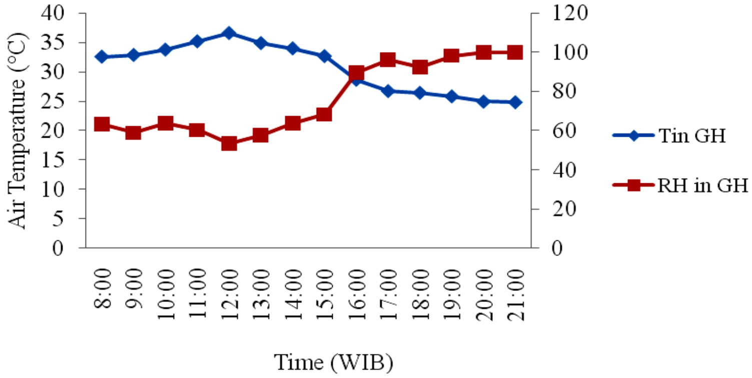

Figure 3. Average air temperature and humidity during potato growth in the lowlands

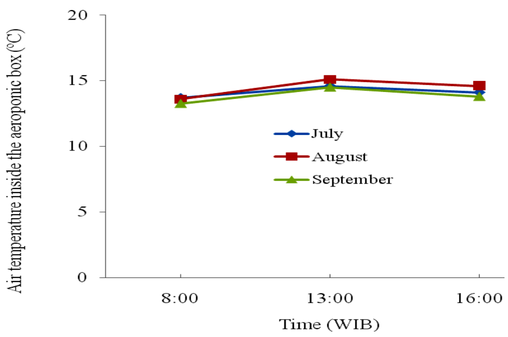

Figure 4. Air temperature in the aeroponic box with the root zone cooling application

The high air temperature in the lowlands during aeroponic planting of potato seeds also causes the upper part of the plant (leaves and stems) to wilt and burn (Sumarni *et al*., 2021). The results of the application of root zone cooling (in the root area) were able to maintain the temperature of the root area of 10-15 °C and controlling evaporative cooling (the upper part of the plant) in this study was able to reduce the temperature around the surface of the plant to an average of 27.3 °C (from the previous one). without evaporative cooling at 35 °C) and increased humidity to 89.6% (Figure 5). These results can reduce the percentage of burning in plant parts as in previous studies (Sumarni *et al*., 2021).

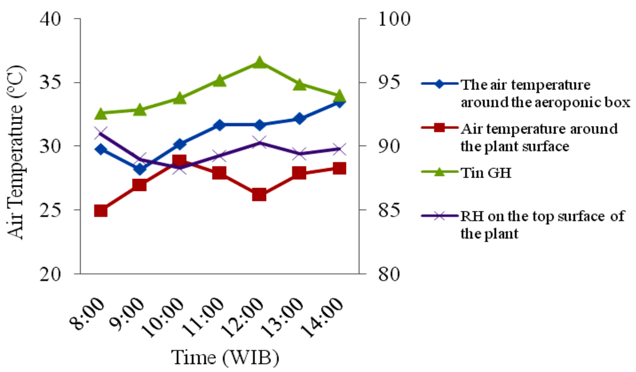

Figure 5. Effect of evaporative cooling on temperature reduction in around the plants.

3.2. Plant Growth

The results of statistical analysis showed that varieties had a significantly different effect on the variables of plant height and number of leaves. Giving different EC concentrations also gave different results on plant height and number of leaves. The combination of EC treatment and variety did not interact with plant height and number of leaves. However, there was an interaction between the combination of EC treatment and variety on the number of tubers.

3.2.1. Plant Height

The results of statistical analysis showed that there was an effect of varietal treatment on plant height variables. The MZ variety from the beginning of growth showed the highest plant growth. However, at the age of 35 days after planting the Granola K variety gave the same plant height response as the MZ variety and the lowest was the Granola L variety. Until the age of 56 days after planting the Granola K variety gave the highest plant height yield with an average plant height of 61, 9 cm compared to the MZ and Granola L varieties. The MZ and Granola K varieties gave the same plant height response, namely 55.6 cm for the MZ and Granola K varieties and 51.9 cm gave the same plant height yield (Table 1).

Table 1. Effect of potato plant varieties on plant height and number of leaves

Treatments	Plant Height (Days After Planting/DAP)					
	21	28	35	42	49	56
MZ	9a	14.1	20.9a	30.2a	41.8a	55.6b
Granola K	7.4b	14.5	20.4a	32.4a	42.3a	61.9a
Granola L	7.3b	13.4	17.9b	27.7b	35.7b	51.9b
	Number of leaves (sheets)					
MZ	20.7a	39ab	61.2a	84.4b	202.0a	280.7a
Granola K	17.7b	41a	62.4a	130.6a	214.4a	272.5a
Granola L	14c	31.4b	43.9b	96.7b	143.5b	180.2b

Note: The numbers followed by the same letter in the same column show no significant difference based on DMRT at the level of = 5%

Potato varieties MZ, Granola K and Granola L are varieties cultivated by farmers in one of the highland potato centers of Indonesia, namely Central Java Province (Nurchayati *et al*., 2019). Through climate modification (creating a climate like the highlands) this variety can grow in the lowlands with increased tuber yields. Granola L plant height in the highlands at the age of 56 day after planting (DAP) reached 72 cm and Granola L reached 50 cm. The plant height yields obtained from this study indicate that potato plants in the lowlands can grow as in the highlands with the given climate engineering. From the results of this study, it is known that the application of root zone cooling and evaporative cooling can create climatic conditions that can help potato plants in the highlands to grow in the lowlands. These results are the creation of temperatures in the root area that can last 10-15 °C and the top area of the plant is 27.3 °C. These results support previous research (Sumarni *et al*., 2013; 2019; 2021). Potatoes are optimally grown in fairly cold climatic conditions such as in tropical highlands with an average daily temperature of 15-20 °C. High temperatures will support plant height and leaf development but inhibit tuber formation. In addition, heat stress will lead to small tubers (Kline & Halseth 1990). Areas with a maximum temperature of 30 °C and a minimum of 15 °C are very good for potato growth than areas with a relatively constant temperature, which is 24 °C (Sukhla & Singh 1975). From the results of this study, the root zone cooling temperature of 10-15 °C can support tuber initiation and control of evaporative cooling can support the growth of aeroponic potatoes on the top of the plant.

Applications of giving different concentrations of nutrient solution EC gave different results to plant height, but there was no interaction from giving different concentrations of nutrient solution to plant height for each potato seed variety used (Table 2). Giving EC1 concentration of 1.5 mS/cm at 1 age-3 weeks (21 DAP) and 2 mS/cm at 4 weeks of harvest gave higher plant height yields than EC 2 (by 1.5 mS/cm). 1 at 1 to 3 weeks (21 DAP) and 3 mS/cm at 4 weeks-harvest). The average plant height of EC1 was 69.1 cm and EC2 was 43.8 cm. This indicates that EC1 is the optimal EC for potato plant height growth, because at EC 1 potato plants do not experience water stress due to salinity conditions in the EC. So at EC1 potato plants reached a higher plant height than EC 2. This is in accordance with previous studies, where EC nutrient solutions of more than 2 mS/cm can be toxic to potato plants thereby inhibiting the growth of aeroponic potato plants (Otazu, 2010).

3.2.2. Number of Leaves

The parameter of the number of leaves indicated there is an influence of variety on the number of leaves. MZ variety from early growth to 56 DAP gave the highest number of leaves compared to Granola K and Granola L varieties (Table 1). However, at 42 DAP to 56 DAP the MZ and Granola K varieties gave the same and higher leaf number response than the Granola L variety. The Granola K variety gave the lowest leaf number response from the beginning of growth to 56 DAP. The MZ variety gave an average leaf count of 280.7 leaves (56 DAP) and the same as Granola K as many as 272.5 leaves (56 DAP). The lowest number of leaves was produced from the Granola L variety as many as 180 leaves (56 DAP).

EC application of different nutrient solutions can have different effects on plant height and number of leaves. From the results of this study, it can be conveyed that the concentration of EC1 (EC 1-2 mS/cm) can provide higher leaf growth than EC2 in potato seed production with an aeroponic system in the lowlands with root zone cooling and evaporative cooling (Table 2).

Table 2. Effect of EC on plant height and number of leaves

Treatments	**Plant Height (Days After Planting/DAP)**					
	21	**28**	**35**	**42**	**49**	**56**
EC1	6,2b	13,7	21,3a	39,5a	49,6a	69,2a
EC2	9,6a	14,2	18,1b	20,7b	30,2b	43,8b
	Number of leaves (sheets)					
EC1	10,1b	27,1b	64,5a	124,6a	239,9a	284,0a
EC2	24,9a	47,1a	47,1b	83	133,4b	204,9b

Note: The numbers followed by the same letter in the same column show no significant difference based on DMRT at the level of = 5%

3.2.3. Growth and Development of Number of Bulbs

The use of potato varieties and EC application of different nutrient solutions interacted with the number of potato seed tubers produced. The combination of treatments for the Granola K variety with EC2 gave the highest number of tubers the same as the Granola L variety with EC2, namely the average number of tubers for each combination was 30 bulbs/plant and 25 bulbs/plant. The lowest number of tubers was produced from the MZ variety with the same EC1 as the combination of Granola K and EC1 varieties, namely 15.1 bulbs/plant and 14.1 bulbs/plant (Figure 6).

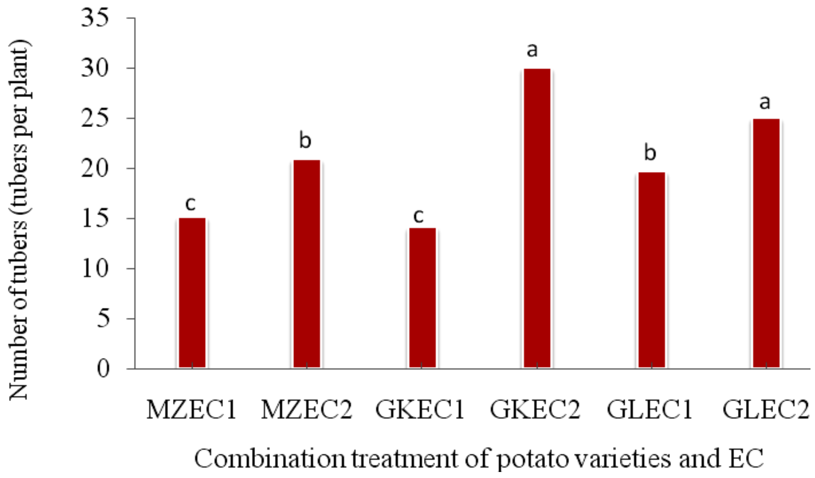

Figure 6. Interaction of variety treatment and EC concentration of nutrient solution on number of bulbs per plant

The results of the number of tubers obtained in this study increased as compared from the previous research, which resulted in the number of bulbs 10 bulbs/plant from the granola variety and EC nutrient solution 1-2 mS/cm and only applied root zone cooling climate engineering (Sumarni *et al*., 2019). Electrical conductivity reflects the concentration of the total total ion in the nutrient solution that affects nutrient absorption, plant growth, productivity and tuber quality (Chang *et al*., 2011). The composition of the solution used depends not only on the concentration of nutrients but also on other factors such as cultivation technique, hydroponic system used, growth environment and phenological phase, plant species and plant cultivar (Furlani *et al*. 1999). Potato cultivars respond differently to tuber number and can be affected by plant spatial arrangement (Santos & Rodriguez, 2008). From other studies, EC concentrations of nutrient solutions of more than 4 mS/cm can cause osmotic stress and ion toxicity (Savvas & Adamidis, 1999). The final result of EC administration of different nutrient solutions can be seen from the number of tubers produced. This is consistent with another study on Barley tubers, where EC had an influence on seed initiation (Lynikiene & Pozeliene, 2003).

4. CONCLUSIONS AND RECOMMENDATION

From the description of the results above, it can be concluded that the MZ and GL varieties are the varieties that have the best response to be used as seeds in an aeroponic system in order to produce large quantities of potato seeds in potato seed production in the lowlands with the application of root zone cooling and evaporative cooling. It is necessary to apply it to several other varieties in potato production centers so as to enrich scientific information on the yield and quality of various seeds used in this aeroponic system to provide an overview and choice for breeders in producing potato seeds.

ACKNOWLEDGMENT

Thanks to the Institute for Research and Community Service at Jenderal Sudirman University for the fund provided through the BLU Applied Research Grant with contract number T/515/UN23.18/PT.01.03/2021 so this research can be carried out.

REFERENCES

Beals, K.A. (2019). Potatoes nutrition and health. *American Journal of Potato Research*, ***96***,102–110. https://doi.org/10.1007/s12230-018-09705-4

BPS (Badan Pusat Statistik). (2014). Luas Panen, Produksi dan Produktivitas Kentang, 2009-2013. Jakarta: Badan Pusat Statistik Republik Indonesia.

Balai Penelitian Tanaman Sayuran. (2017). Produksi Benih Kentang (*Solanum tuberosum* L.). www.balitsa.litbang.pertanian.go.id.

Chang, D.C., Cho, I.C., Suh, J.T., Kim, S.J., & Lee, Y.B. (2011). Growth and yield response of three aeroponically grown potato cultivars (*Solanum tuberosum* L.) to different electrical conductivities of nutrient solution. *American Journal of Potato Research*, ***88***(6), 450–458. https://doi.org/10.1007/s12230-011-9211-6

Dianawati, M., & Wattimena, G.A. (2014). Potensi teknologi aeroponik dalam mendukung swasembada benih kentang nasional. *Prosiding Seminar Nasional PERHORTI*. Malang. 5-7 November 2014, 260-266.

FAO (Food and Agriculture Organization). (2011). *FAOSTAT Database*. Rome.

Furlani, P.R., Silveira, L.C.P., Bolonhezi, D., & Faquin, V. (1999). *Cultivo hidropônico de plantas*. Campinas: Instituto Agronômico, 52p.

Gastelo, M., Bonierbale, M., & Kleinwechter, U. (2014). Global Potato reseacrh for a changing word. *Working Paper*. Internasional Potato Center (CIP), Lima, Peru. https://doi.org/10.4160/9789290604426

Greenway, H., & Munns, R. (1980). Mechanisms of salt-tolerance in nonhalophytes. *Annual Review of Plant Physiology*, ***31***(1), 149–190. https://doi.org/10.1146/annurev.pp.31.060180.001053

Henny, H., Murtilaksono, K., Sinukaban, N., & Tarigan, S.D. (2011). Erosi dan kehilangan hara pada pertanaman kentang dengan beberapa system guludan pada andisol di hulu DAS Merao Kabupaten Kerinci, Jambi. *Jurnal Solum*, ***8***(2), 43-51. https://doi.org/10.25077/js.8.2.43-51.2011

Kline, R.A., & Halseth, D.E. (1990). *Growing Potatoes in the Home Garden*. VC Report 669, Department of Vegetable Crops, Cornell University.

Levy, D., & Veilleux, R.E. (2007). Adaptation of potato to high temperatures and salinity. *American Journal of Potato Research*, ***84***(6), 487–506. https://doi.org/10.1007/BF02987885

Lynikiene, S., & Pozeliene, A. (2003). Effect of electrical field on barley seed germination stimulation. *CIGR E-Journal*, ***5***, manuscript FP 03 007.

Lutaladio, N., Ortiz, O., Haverkortz, A., & Caldiz, D. (2009). *Sustainable Potato Production. Guidelines for Developing Countries*. Rome: Food and Agriculture Organization, 96p.

Mulyono, D., Anwar, J., & Sayekti, L. (2017). Kelas benih kentang (*Solanum tuberosum* L.) berdasarkan pertumbuhan, produksi, dan mutu produk. *Jurnal Hortikultura*, ***27*** (2), 209-216. http://dx.doi.org/10.21082/jhort.v27n2.2017.p209-216

Nurchayati, Y., Setiari, N., Dewi, N.K., Meinaswati, F.S. (2019). Karakterisasi morfologi dan fisiologi dari tiga varietas kentang (*Solanum tuberosum* L.) di Kabupaten Magelang, Jawa Tengah. *NICHE Journal of Tropical Biology*, ***2***(2), 38-45. https://doi.org/10.14710/niche.2.2.38-45

Otazu, V. (2010). *Manual on Quality Seed Potato Production Using Aeroponics*. International Potato Center (CIP), Lima, Peru.

Santos, B.M., & Rodriguez, P.R. (2008). Optimum in-row distances for potato mini tuber production. *Hortechnology*, ***18***(3), 403-406. https://doi.org/10.21273/HORTTECH.18.3.403

Sayaka, B., & Hestina, J. (2011). Kendala adopsi benih bersertifikat untuk usaha tani kentang. *Jurnal Forum Penelitian Agro Ekonomi*, ***29***(1), 27-41.

Savvas, D., & Adamidis, K. (1999). Automated management of nutrient solutions based on target electrical conductivity, pH, and nutrient concentration ratios. *Journal of Plant Nutrition*, ***22***(9), 1415–1432. https://doi.org/10.1080/01904169909365723

Sumarni, E., Herry, S., Kudang, B.S., & Satyanto, K.S. (2013a). Aplikasi pendinginan zona perakaran (*Root Zone Cooling*) pada produksi benih kentang menggunakan sistem aeroponik. *Jurnal Agronomi Indonesia*, ***41***(2), 154-159. https://doi.org/10.24831/jai.v41i2.7522

Sumarni, E., Herry, S., Kudang, B.S., & Satyanto, K.S. (2013b). Seed potato production using aeroponics system with zone cooling in wet tropical lowlands. *Acta Horticulturae*, ***1011***, 141-145. https://doi.org/10.17660/ActaHortic.2013.1011.16

Sumarni, E., Sumartono, G.H., & Satyanto, K.S. (2013c). Aplikasi *zone cooling* pada sistem aeroponik kentang di dataran medium tropika basah. *Jurnal Keteknikan Pertanian*, ***1***(1): 99-106. https://doi.org/10.19028/jtep.01.1.%25p

Sumarni, E., Farid, N., Sugiarto, A.N., & Sudarmadji, A. (2016). G0 seed potential of the aeroponics potatoes seed in the lowlands with a root zone cooling into G1 in the highlands. *Rona Teknik Pertanian*, ***9***(1), 1-10. https://doi.org/10.17969/rtp.v9i1.4380

Sumarni, E., Hardanto, A., & Arsil, P. (2021). Effect of root zone cooling and evaporative cooling in greenhouse on the growth and yield of potato seed by aeroponics in tropical lowlands. *CIGR Journal*, ***23***(1), 28-35.

Sumarni, E., Noor, F., Darjanto, Ardiansyah, & Loekas, S. (2019). Effect of electrical conductivity (EC) in the nutrition solution on aeroponic potato seed production with root zone cooling application in tropical lowland, Indonesia. *CIGR Journal*, ***21***(2), 70-78.

Sumarni, E., N. Farid, L. Soesanto, & J. Juansah. (2018). Pengaruh waktu pemberian nutrisi dengan aplikasi *root zone cooling* terhadap pertumbuhan dan perkembangan tanaman aeroponik di dalam *greenhouse* dataran rendah tropis. *Jurnal Teknik Pertanian Lampung*, ***7***(3),142-150. http://dx.doi.org/10.23960/jtep-l.v7.i3.142-150

Teixeira, J., & Pereira, S. (2007). High salinity and drought act on an organ-dependent manner on potato glutamine synthetase expression and accumulation. *Environmental and Experimental Botany*, ***60***(1), 121–126. https://doi.org/10.1016/j.envexpbot.2006.09.003