Effect of electrical conductivity

by Eni Sumarni

Effect of electrical conductivity (EC) in the nutrition solution on aeroponic potato seed production with root zone cooling application in tropical lowland, Indonesia

Eni Sumarni[1*], Noor Farid[2], Darjanto Darjanto[2], Ardiansyah Ardiansyah[1], Loekas Soesanto[2]

(1. *Departement of Agricultural Technology. Faculty of Agricultural. Jenderal Soedirman University. Purwokerto. Jl. dr. Suparno. Karangwangkal. Postal Code.53123*;
2. *Department of Agrotechnology. Faculty of Agricultural. Jenderal Soedirman University. Purwokerto. Jl. dr. Suparno, Karangwangkal. Postal code. 53123*)

Abstract: Production of potato seeds aeroponically in wet tropical lowland with root zone cooling application has been successfully obtained. However, Research on nutrition management is still needed. The growth and development of potato crop in the lowland with root zone cooling application was still facing many withered, dry or yellowing leaves. Electrical Conductivity (EC) concentration of potato seed growth and yield on aeroponics system with root zone cooling application in the lowland has not been widely studied. The purpose of this research was to study and get the effect of EC of the nutrition solution on growth and yield of potato seed on potato seed production aeroponically with root zone cooling application in tropical lowland. This research was conducted at an altitude of 115 m asl. The experiment used a randomized block design with four replicates. The pH of the nutrient solution used was 5-6.5. The variety used was Granola. Factors tested: 1. Electric Conductivity (EC): EC1 (1 mS cm^{-1} in the first three weeks, and 2 mS cm^{-1} in the 4th week to harvest), EC2 (1 mS cm^{-1} in the first three weeks, and 4 mS cm^{-1} in the 4th week to harvest) and EC3 (1 mS cm^{-1} in the first three weeks, and 6 mS cm^{-1}), 2. Initial seed (B): B1 (cuttings of tissue culture 1 and B2 of tissue culture 2). The data were analyzed by F test and continued with Duncan's Multiple Range Test of 5% level. The result showed that EC1 with Cuttings 1 and Cuttings 2 of tissue culture gave the highest plant height and number of leaves and the lowest number on EC3 both cuttings 1 and cuttings 2. EC1 with Cuttings 1 gave the highest tubers numbers (10.8 tubers) of plant yield and the lowest of EC 3 did not produce tuber. EC1 with cuttings 2 produced the highest tuber weight as 1.78 grams. In conclusion, the best EC for potato seed production with aeroponics system root zone cooling application was EC 1 mS cm^{-1} in the first three weeks, and 4 mS cm^{-1} in the 4th week to harvest) for all cuttings.

Keywords: Aeroponics, potato seed, tropical lowland, EC, hydroponics, nutrition, root zone cooling

Citation: Sumarni, E., N. Farid, D. Darjanto, A. Ardiansyah, and L. Soesanto. 2019. Effect of electrical conductivity (EC) in the nutrition solution on aeroponic potato seed production with root zone cooling application in tropical lowland, Indonesia. Agricultural Engineering International: CIGR Journal, 21(2): 70–77.

1 Introduction

The growth rate of potato production in Indonesia in 2010-2014 is still fluctuating, even below 4.13% (Republic of Indonesia Departement of Agriculture, 2015) and still the lowest potato production country compared to China, India, Pakistan and Bangladesh. Indonesian potato production ranges is 16.02 tons per hectare. To meet the needs of potatoes, Indonesia is still importing. Potato import is obtained with amount of 24,471 and 11,917 tons from the US and Australia, respectively, in the year 2014. The problems of potato production are

Received date: 2018-03-29 **Accepted date:** 2018-06-07

* **Corresponding author: Eni Sumarni,** Email: Ph.D., Associate Professor, Departement of Agricultural Technology, Jenderal Soedirman University. Purwokerto. Jl. dr. Suparno. Karangwangkal. Postal Code. 53123. Email: arny0565@gmail.com. Tel: +6281391396079, Fax: (+62281) 638791

caused by the low number and quality of seeds. The availability of new potato seeds reaches 6% by the total seed requirement (Republic of Indonesia Directorat General of Agriculture Seedling and Mechanization, 2008). Potato seeds used by farmers are mostly decreased in quality because they are used for more than five generations. In addition, most areas of potato planting in the highland are endemic bacteria, viruses and pathogens that attack potato plants. Therefore, enhancement technology of potato seeds and the development of planting areas are needed in order to support potato self-sufficiency and reduce import.

The production of potato seeds conventionally produces 5-10 tubers of crop (Otazu, 2010). Production of potato seeds using pot produces 3-7 tubers per plant (Daniels et al., 2000) and uses nutrient film technique (NFT) system (Ricardo et al., 2009) and substrate media have also been performed. However, NFT system has disadvantage, such as the poor aeration of root areas (Rolot et al., 2002) and tuber initiation on solid media is slower than porous media (Tibbitts and Cao, 1994). The aeroponics system today becomes a technology to accelerate production improvement of potato seeds. The aeroponics system has been used for commercial production in China and Korea. The aeroponics system in Peru is capable of producing more than 100 tubers per plant (Otazu, 2010; Nugaliyadde et al., 2005). However, aeroponics technology for potato seed production in the lowland has not been widely implemented. Technology of potato seed production using aeroponics system in lowland and root zone cooling application begins to be studied and produces tubers (Sumarni et al., 2013a). This technology is a novelty technology, because generally, the aeroponics technology of potato seed production is implemented in the highland. Aeroponics is one of hydroponics technology that can avert plants from the contamination of nutrient overtopping to the surface and groundwater (Thapa et al., 2016; Carvalho et al., 2015).

The development of potato cultivation into the lowland is an effort to help the production improvement of potato seeds. Cultivation of potatoes in the lowlands is constrained by high temperature, because it is not suitable for growth and initiation of potato tuber. It can be overcome with aeroponics system and root zone cooling application (Sumarni et al., 2013a). The production of potato seeds in lowland (250 m asl) has been conducted and produced the highest tuber (at 10°C) about 579 tubersm^{-2} (Sumarni et al., 2013a) and a height of 115 m asl (Sumarni et al., 2016). Until now, aeroponics technology is a new hope for production improvement of potato seeds. The weaknesses of this technology are the dependence on electricity (Farran and Castel 2006; Chang et al., 2012), high investment costs (Mateus-Rodriguez et al., 2013), and still lack of complete information about aeroponics technology in each country. These difficulties include information related to nutrition for aeroponic potatoes in Indonesia.

Nutrition is an important factor for producing excellent and high-grade seeds (Tessema et al., 2017). The success of aeroponics is determined by the electrical conductivity (EC) of the nutrient solution. EC reflects the total ions contained in the nutrient solution. The EC concentration affects the nutrient absorption at plant growth stage, productivity and quality of tubers (Chang et al., 2011). EC is also used as a health indicator of nutrient solution. Potato plant is one of plants that are sensitive to EC. Application of EC, which is not compatible with plant growth, may cause toxic for plants (Teixeira and Pereira, 2007). The effects of EC that are not compatible with growth and yield of potato tuber plants on the ground cause plant growth to be inhibited, tuber yields are reduced and changes occur in the content of dry matter, solids are soluble and secondary metabolite in tubers (Levy and Veilleux, 2007). The high nutrient solution EC causes water deficit due to reduction of osmotic potential of nutrient solution, greater availability of ions in nutrient solution or excessive ion absorption (Greenway and Munns, 1980).

The concentration of nutrient solution on the production of hydroponic lettuces with cooling application has been investigated, the result shows that the increase in the temperature of the nutrient solution affects the EC. Increased EC does not decrease plant productivity if the maximum air temperature of the nutrient solution is constrained to condition that is still optimal for plants (Cometti et al., 2013). In addition, potato varieties give responds differently concerning tuber yield (Santos and Rodriguez, 2008). EC 2,1 and 2,1 dS m^{-1} give the highest yield for Agata and Asterix varieties in Brazil (Calori et al., 2017).

The way EC concentration to the growth and yield of potato seed yield on aeroponics system with root zone cooling application for production of seed potato in lowland has not been studied a lot. Hence, the purpose of this research is to know and to get the effect of EC of the nutrient solution to the growth and yield of potato seeds on potato seed production aeroponically with *root zone cooling* application in tropical lowland.

2 Materials and methods

This research was conducted from April to September 2016. This research location located at 115 m asl altitude in the *greenhouse* of the Faculty of Agriculture, Jenderal Soedirman University, Purwokerto, Indonesia. Location altitude at 115 m asl was lowland, so *root zone cooling* system was needed to adjust the growth and potato tuber initiation.

2.1 Root zone cooling application

The *root zone cooling* application was implemented by cooling in the root area of potato plant that planted aeroponically within the *greenhouse*. Cooling process was provided by spraying a cold nutrient solution with a temperature of 10°C. Nutrient solution was administered using timer automatically. The construction and workings of the aeroponic system with root zone cooling have been used in previous studies to obtain the appropriate temperature of the root zone cooling (Sumarni et al., 2013b). The aeroponic containers used are 1.5 m (long) × 1 m (wide) × 1 m (high). The outermost aeroponic container material of multiplex wood thickness 12 mm, the inside insulated with styrofoam thickness of 2 cm. Styrofoam as a place of plants using a thickness of 3 cm. Planting distance 15 cm×15 cm, so that in one container aeroponik there are 45 plants. High pressure pump to drain nutrients through nozzles to the roots of plants. The timer is used to control the time of nutrient spraying, the chiller used to cool the nutrients, and the dye pump to drain the nutrients to be cooled into the chiller (Figure 1). The duration of the nutrient solution was 3 minutes of turning on and 5 minutes of turning off (Sumarni et al., 2013b, 2013c; Sumarni and Sumartono et al., 2013a; Sumarni et al., 2013d).

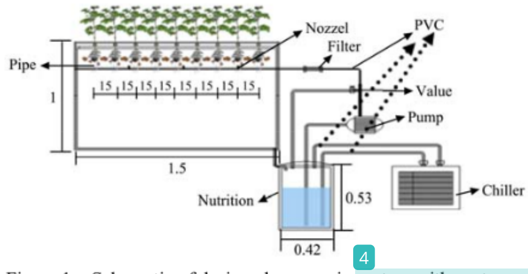


Figure 1 Schematic of designed aeroponic system with root zone cooling (Sumarni, Herry and Kudang et al., 2013b)

2.2 Experimental design and analytical data

The experiment used a randomized block design (RAK) with four repetitions. The pH of the nutrient solution used was 5-6.5. Potato varieties used were Granola by tissue culture. Factors that were tested:

1. EC: EC1 (1 mS cm^{-1} in the first three weeks, and 2 mS cm^{-1} in the 4th week until harvest), EC2 (1 mS cm^{-1} in the first three weeks, and 4 mS cm^{-1} in the 4th week until harvest), EC3 (1 mS cm^{-1} in the first three weeks, and 6 mS cm^{-1}).

2. Initial seed (B): B1 (cuttings 1) and B2 (cuttings 2).

Plant growth parameters observed included plant height, number of leaves and crop yield (number of tuber, and tuber weight). The data of growth observation and result were analyzed by *F* test and continued with Duncan's Multiple Range Test (UJGD) 5% level.

3 Results and discussion

3.1 Micro-climate of potato growth in lowland greenhouse during the study

The air temperature inside the *greenhouse* during the growth and development of the potato plant was not optimal for the growth and initiation of potato seed tuber that planted aeroponically. The condition of the potato plant roots hung in the air (inside the aeroponic box) was susceptible to high temperature in the *greenhouse* (Figure 2). The average air temperature inside the *greenhouse* during the daylight (12:00 o'clock) could reach a temperature of 36°C and the daily average reached 30°C. The high temperature in the lowland becomes an inhibitor of the potato seed production (Sumarni et al., 2013b, 2013c; Sumarni et al., 2013d). Hence, it is necessary to microclimate engineering effort in order to make potato plants can grow in the lowland.

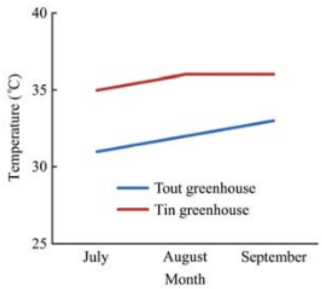


Figure 2 Temperatures outside and inside the greenhouse

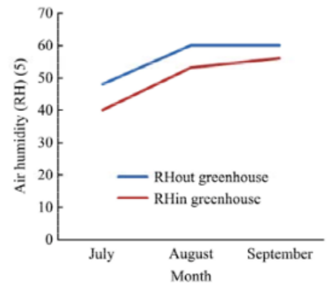


Figure 3 Air humidity during the study

Potato plant is a plant that can grow optimally in a cold temperate highland, with an average of daily temperature range from 15°C-21°C (Pereira and Shock, 2005; Lovatt, 1997). High temperature will support leaf development, but it inhibits tuber formation. Besides, hot environmental condition continuously will lead to small tubers (Kline et al., 1990). The temperature of the rooting area (soil) affects the time between planting and sprouting (Government of Alberta Agriculture and Rural Development, 2003). The early appearance of shoot has a linear relationship between ground temperature and daily temperature fluctuation, and optimum temperature between 22°C-24°C. At temperature above the optimum when the initial shoot appeared will be inhibited (Pereira and Shock, 2005).

Air humidity during measurement also shows that the humidity of the air inside and outside the lowland greenhouse is very low and not optimal for the growth of potato plants (Figure 3). The air humidity inside the greenhouse is in average 50%, while outside the greenhouse is 56%. The humidity of potato growth environment affects the evapotranspiration process, which is the power to lift up water and nutrient from the root to the plant canopy. The average humidity of the potato plant is 80%-90%. The air humidity, which is too high, causes a small evapotranspiration, whereas too low humidity causes evapotranspiration to increase, so that more volatile water is absorbed by the roots. High humidity can be caused by too dense spacing and overgrown plant canopy, which will lead to fungal disease. It causes the plant cells lose turgor pressure, the tissue contracts and the plants will wilt. Root zone cooling technology is one of the efforts to keep the temperature of rooting areas are in cold condition appropriate with the optimal area of potato growth.

3.2 Plant height and number of leaves

The result of EC giving of different nutrient solution also gave different effect on the number of leaves and the height of the potato plant. This is in accordance with the other studies on Barley tuber, where electricity has an effect on seed initiation (Lynikiene and Pozeliene, 2003). The plant height and the best number average of leaf obtained from EC1 with initial seed from either cuttings 1 or cuttings 2. EC1 with cuttings 1 gave plant height 40 cm and EC1 with cuttings 2 produced plant height 41.3 cm at 65 hst. EC1 giving with cuttings 1 until the plants were at 65-hst gives 81.5 strands and no different from EC1 with cuttings 2 at the rate of 84.8 strands (Table 1). These results indicate that cuttings 1 and cuttings 2 can be used for potato seed production in lowland aeroponically with root zone cooling application.

Table 1 Interaction of EC giving and potato seed cuttings to plant height and number of leaves

Treatment	Number of leaves 65 HST	Plant Height 65 HST (cm)
EC1 Cuttings 1	81.5 a	40.0 a
EC1 Cuttings 2	84.8 a	41.3 a
EC2 Cuttings 1	25.8 b	10.8 b
EC2 Cuttings 2	15.3 c	12.8 b
EC3 Cuttings 1	1.8 d	1.3 c
EC3 Cuttings 2	1.3 d	1.3 c

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

Initial seed from cuttings will be easier for the growth treatment than planting the seeds from tuber for production aeroponically. It is because it takes time until the emergence of plant roots under *styrofoam* (aeroponics chamber). The use of seedling from seed in an aeroponics installation also makes possible the seed being rot during the growth of the shoot. Cuttings 1 and cuttings 2 are still well used for production. The more generation of cuttings, so the growth of plant will decrease. The 8th cuttings of potato plant provides the lowest plant vigor compared to the previous cuttings generation as well as the growth of plant height (Mamun et al., 2016; Yasmin, 2008).

3.3 Number of tubers and tuber weight of potato seed produced

EC giving and the use of the early seeding cuttings of potato plants gave different result. EC 1 produced the highest average number of potato seeds as much as 10.8 pieces of crop while the lowest on EC 3 was not bulbous. EC 1 gave the highest average weight of tuber with cuttings 2 was 1.78 grams and the lowest was EC 3 because the plant was not bulbous (Table 2).

Table 2 Interaction of EC giving and seed potato cuttings on quantity and weight potato seed

Treatment	Number of Tuber (piece)	Tuber Weight (gram)
EC1 Cuttings 1	10.8 a	1.33 b
EC1 Cuttings 2	6.0 b	1.78 a
EC2 Cuttings 1	3.0 c	0.97 c
EC2 Cuttings 2	1.8 c	0.78 c
EC3 Cuttings 1	0,0 d	0.0 d
EC3 Cuttings 2	0.0 d	0.0 d

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

From this result, it was found out that the higher the EC value, so the potato seed production aeroponically in the lowland with root zone cooling application was getting descend. The high EC concentration led to absorption of nutrient and water reduced, sodium and chloride toxicity in stem cell and the ability of plant photosynthesis decreased (Ali et al., 2004; Amel et al., 2016). This result showed that the EC that can be used for the production of potato seed in the tropical lowland with root zone cooling is EC 1-2 mS cm^{-3}.

The total concentration of nutrient solution ion determines the growth, development and production of the plant. The total amount of ion in the nutrient solution provides an osmotic pressure (Landowne, 2006). From the result of plant height growth, and number of potato leaves (Table 1) and seed tuber yield (Table 2); it is found out that the higher the EC of the nutrient solution, so the growth and yield decreased. EC 3 (1 mS cm^{-1} 6 mS cm^{-1}) results in the growth and yield of the lowest seed tubers compared to the other EC. It can be caused by osmotic stress condition in the root zone, resulting in the decreased of leaf turgor and decreased of expansion to leaves (Huang and Redmann, 1995). The condition is correlated with stomatal closure or reduction in total chlorophyll concentration in the leaves (Romero-Aranda and Syvertsen, 1996). Plants, which are exposed to root areas with high EC experience stunted growth (Zhu, 2002). The research result of EC of the nutrient solution on aeroponic potato seed production with root zone cooling application in the lowland showed that EC 3 (1 mS cm^{-1} in the first three weeks and 6 mS cm^{-1}) experienced the highest growth of plant and the lowest number of leaves compared to EC1 and EC2. The potato plant roots at EC3 did not develop and the freshness decreased, but EC1 is good (Figure 4 and 5).

Figure 4 Condition of aeroponic potato root with root zone cooling in lowland at EC 1

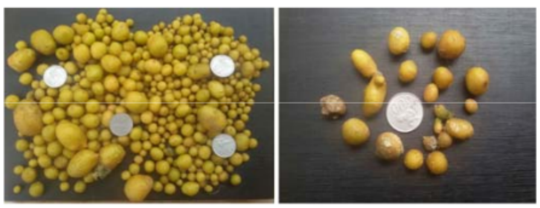
A B

Figure 5 Condition of aeroponic potato root with root zone cooling in lowland on EC 2 (A) and EC 3 (B)

The results of this study are in accordance with previous research on tomato plants, that is the plant height growth, number of leaves, and stomatal density decreased with increasing electrical conductivity (Romero-Aranda et al., 2001). Decreased osmotic pressure of EC of the nutrient solution became the dominant factor of growth and development decline (Reina et al., 2005). The effect of EC of nutrient solution on hydroponics, growing media (substrate) and irrigation frequency in photosynthetic response of plant showed that leaf photosynthesis rate increased by 15.4% and 14.1% when EC increased 2.5-4.0 dS m^{-1} for plants in the greenhouse (Xu et al., 1995). However, an increase in EC to 5.5 dS m^{-1} resulted in a 10% lower photosynthetic rate than EC 4.0 dSm^{-1}.

The EC increase of 1.25 dS m^{-1} to 8.75 dS m^{-1} did not reduce the leaf of photosynthetic rate of tomato plant (Schwarz et al., 2002).

The research result of production of potato mini tuber with closed hydroponics technique using sand media, it was found out that the increase of EC of the nutrient solution up to 5,8 did not affect the number of tuber, but it decreased the freshness and weight of tuber. The use of EC of the nutrient solution 1 dS m^{-1} can be used for potato seed propagation derived from planlet or mini tuber (Novella et al., 2008). The result of this study supports the result of research of potato seed production in aeroponics system in the lowland with EC difference. The higher EC (EC3) indicates a less healthy root condition than EC1 and EC2 (Figure 4) and tuber yield in Figure 6.



A B

Figure 6 The appearance of aeoponic potato seeds with root zone cooling in the lowland EC 1 (A) and EC 3 (B)

4 Conclusion

From the result above, it can be concluded that EC1 with cuttings 1 and cuttings 2 tissue culture result gave the highest plant height, number of leaves, and the highest potential number of tubers, while EC3 either cuttings 1 or cuttings 2 did not produce tuber. The highest potential number of tubers that can be achieved by EC 1 with cuttings 1 was 10.8 crop seed. The highest tuber weight was obtained from EC1 with cuttings 2 of 1.78 grams.

Acknowledgement

Thank you to KemenristekDikti for the National Strategic Grant Funding in 2016 that was granted (No. 2045/UN23.14/PN/2016), so that this research can be conducted.

References

Ali, Y., Z. Aslam, M. Y. Ashraf, and G. R. Tahir. 2004. Effect of salinity on chlorophyll concentration, leaf area, yield and yield components of rice genotypes grown under saline environment. *International Journal of Environmental Science & Technology*, 1(3): 221–225.

Amel, M. B., G. Hiba, M. H. D. Boutheina, and B. Abdehamid. 2016. Water use efficiency of potato crop irrigated under Tunisian climatic condition. *Scientia*, 11(1): 38–41.

Calori, A. H., T. L. Factor, J. C. Feltran, E. Y. Watanabe, C. C. de Moraes, and L. F. V. Purquerio. 2017. Electrical conductivity of the nutrient solution and plant density in aeroponic production of seed potato under tropical conditions (winter/spring). *Bragantia*, 76(1): 23–32.

Carvalho, R. O. D., L. C. N. Weymar Jr, C. B. Zanovello, M. L. G. S. D. Luz, G. I. Gadotti, C. A. S. D. Luz, and M. C. Gomes. 2015. Hydroponic lettuce production and minimally processed lettuce. *CIGR Journal*, Special issue May, 2015: 18th World Congress of CIGR: 290–293.

Chang, D. C., I. C. Cho, J. T. Suh, S. J. Kim, and Y. B. Lee. 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.

Chang, D. C., C. S. Park, S. Y. Kim, and Y. B. Lee. 2012. Growth and tuberization of hydroponically grown potatoes. *Potato Research*, 55(1): 69–81.

Cometti, N. N., D. M. Bremenkamp, K. Galon, L. R. Hell, and M. F. Zanotelli. 2013. Cooling and concentration of nutrient solution in hydroponic lettuce crop. *Horticultura Brasileira,* 31(2): 287–292.

Daniels, J., A. S. Pereira, and G. R. L. Fortes. 2000. *Verticalização da Produção de Batata-Semente por Produtores de Agricultura Familiar No Rio Grande do Sul*. Pelotas: Embrapa Clima Temperado.

Farran, I., and M. Castel. 2006. Potato minituber production using aeroponics: effect of plant density and harvesting intervals. *American Journal of Potato Research*, 83(1): 47–53.

Government of Alberta Agriculture and Rural Development. 2003. *Guide to Commercial Potato Production on the Canadian Prairies*. Portage la Prairie, Manitoba R1N 3B9: Western Potato Council.

Greenway, H., and R. Munns. 1980. Mechanisms of salt-tolerance in nonhalophytes. *Annual Review of Plant Physiology*, 31(1): 149–190.

Huang, J., and R. E. Redmann. 1995. Salt tolerance of *Hordeum* and *Brassica* species during germination and early seedling growth. *Canadian Journal of Plant Science*, 75(4): 815–819.

Kline, R. A., D. E. Halseth, and E. Donald. 1990. Growing potatoes in the home garden. VC Report 669. New York: Department of Vegetable Crops, Cornell University.

Landowne, D. 2006. *Cell Physiology*. Miami, FL.: McGraw-Hill

Medical.

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

Lovatt, J. L. 1997. *Potato Information Kit. The Agrilink Series*. Queensland: The State of Queensland, Department of Primary Industries.

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

Mamun, M. A. A., A. A. Mahmud, M. Zakaria, M. M. Hossain, and M. T. Hossain. 2016. Effect of planting times and plant densities of top cuttings on multiplication of breeder seed potato. *Agriculture and Natural Resources*. 50(1): 26–31.

Mateus-Rodriguez, J. R., S. Haan, J. L. Andrade-Piedra, L. Maldonado, G. Hareau, I. Barker, C. Chuquillanqui, V. Otazú, R. Frisancho, C. Bastos, A. S. Pereira, C. A. Medeiros, F. Montesdeoca, and J. Benítez. 2013. Technical and economic analysis of aeroponics and other systems for potato mini-tuber production in Latin America. *American Journal of Potato Research*, 90(4): 357–368.

Novella, M. B., J. L. Andriolo, D. A. Bisognin, C. M. Cogo, and M. G. Bandinelli. 2008. Concentration of nutrient solution in the hydroponic production of potato minitubers. *Ciência Rural*, 38(6): 1529–1533.

Nugaliyadde, M. M., H. D. M. Silva, R. Perera, D. Ayiyaratna, and U. R. Sangkkara. 2005. An aeroponics system for the production of pre basic seed of potato. *Annals of the Sri Lanka Department of Agriculture*, 7, (1): 199–208.

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

Pereira, A. B., and C. C. Shock. 2005. A Review of Agrometeorology and Potato Production. Available at: www.agrometeorology.org/fileadmin/insam/repository/gamp chapter13e. Accessed 20 May 2013.

Reina-Sanchez, A., R. Romero-Aranda, and J. Cuartero. 2005. Plant water uptake and water use efficiency of greenhouse tomato cultivars irrigated with saline water. *Agricultural Water Management*, 78(1-2): 54–66.

Republic of Indonesia Directorat General of Agriculture Seedling and Mechanization . 2008. *Pedoman Perbenihan Kentang*. Jakarta: Direktorat Jenderal Hortikultura.

Republic of Indonesia Departement of Agriculture. 2015. Rencana Strategis Kementrian Pertanian Tahun 2015-2019. Indonesia. Jakarta.

Rolot, J. H., H. Seutin, and D. Michelante. 2002. Production of minerals of the soil in the hydroponics: Evaluation of the system combinant techniques "NFT" and "Gravel Culture" for the development of nutrient solutions. Biotechnology, Agronomy, Société et Environment, 6 (3): 155-161.

Romero-Aranda, R., and J. P. Syvertsen. 1996. The influence of foliar-applied urea nitrogen and saline solutions on net gas exchange of citrus leaves. *American Society for Horticultural Science*, 121(3): 501–506.

Romero-Aranda, R., T. Soria, and J. Cuartero. 2001. Tomato plant-water uptake and plantwater relationships under saline growth conditions. *Plant Science*, 160(2): 265–272.

Ricardo, M. C., E. D. P. P. Jose, F. Valdemar, A. B. P. P. Ce'sar, and S. R. Erika. 2009. The production of seed potato by hydroponic methods in Brazil: Fruits, vegetables and biotechnology. *Global Science Books*, 3(1): 133–139.

Santos, B. M., and P. R. Rodriguez. 2008. Optimum in-row distances for potato mini tuber production. *Hortechnology*, 18(3): 403–406.

Schwarz, D., H. P. Klaring, M. W. Van Iersel, and I. T. Ingram. 2002. Growth and photosynthetic response of tomato to nutrient solution concentration at two light levels. *Journal of the American Society for Horticultural Science*, 127(6): 984–990.

Sumarni, E., A. Sudarmaji, H. Suhardiyanto, S. K. Saptomo. 2016. Produksi benih kentang sistem aeroponik dan *root zone cooling* dengan pembedaan tekanan pompa di dataran rendah. *Jurnal Agronomi Indonesia (Indonesian Journal of Agronomy)*, 44(3): 299–305.

Sumarni, E., G. H. Sumartono, and S. K. Saptomo. 2013a. Aplikasi *zone cooling* pada sistem aeroponik kentang di dataran medium tropika basah. *Jurnal Keteknikan Pertanian*, 1(1): 99–106.

Sumarni, E., S. Herry, B. S. Kudang, and S. K. Saptomo. 2013b. Aplikasi pendinginan zona perakaran (*root zone cooling*) pada produksi benih kentang menggunakan sistem aeroponik. *Jurnal Agronomi Indonesia (Indonesian Journal of Agronomy)*, 41(2): 154–159.

Sumarni, E., S. Herry, B. S. Kudang, S. K. Saptomo. 2013c. Perpindahan panas pada aeroponik chamber dengan aplikasi *zone cooling*. *Jurnal Biofisika*, 9 (1): 8–19.

Sumarni, E., S. Herry, and S. K. Saptomo. 2013d. Seed potato production using aeroponics system with zone cooling in wet tropocal lowlands. In *Proceeding Second Asia Pacific Symp. on Postharvest Research, Education and Extension: APS 2012 1011,* 41–145. Yogyakarta : 18-20 September.

Teixeira, J., and S. Pereira. 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.

Tessema, L., A. Chindi, G. W. Giorgis, A. Solomon, E. Shunka, and E. Seid. 2017. Determination of nutrient solutions for potato (*solanum tuberosum* l.) seed production under aeroponics production system. *Open Agriculture*, 2(1): 155–159.

Thapa, A., S. Rahman, and C. W. Lee. 2016. Remediation of nutrients runoff from feedlot by hydroponic treatment. *CIGR Journal*, 18(1): 1–18.

Tibbitts, T. W., and W. Cao. 1994. Solid matrix and liquid culture procedures for growth of potatoes. *Advanced Space Research*, 14(11): 427–433.

Xu, L., L. Gauthier, and A. Gosselin. 1995. Effects of fertigation management on growth and photosynthesis of tomato plant grown in peat, rockwool and NFT. *Scientia Horticulturae*, 63(1-2): 11–20.

Yasmin, M. F. 2008. Effect of planting time and plant density of top shoot cuttings in potato production. M.S. thesis, Salna, Gazipur: Department of Horticulture, Bangabandhu Sheikh Mujibur Rahman Agricultural University.

Zhu, J. K. 2002. Salt and drought stress signal transduction in plants. *Annual Review of Plant Biology*, 53(1): 247–273.

Effect of electrical conductivity

ORIGINALITY REPORT

15%	14%	10%	3%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	doaj.org Internet Source	2%
2	citeseerx.ist.psu.edu Internet Source	2%
3	lib.dr.iastate.edu Internet Source	2%
4	jurnal.unpad.ac.id Internet Source	2%
5	www.aimspress.com Internet Source	1%
6	R F Lhokitasari, M Hayati, M Rahmawati. "Growth and production of potato mini tubers (Solanum tuberosum L.) in the aeroponic system by root zone treatment and concentration of leaf-fertilizer", IOP Conference Series: Earth and Environmental Science, 2022 Publication	1%
7	jurnal.polinela.ac.id Internet Source	1%

8	garuda.ristekdikti.go.id Internet Source	1 %
9	www.tandfonline.com Internet Source	1 %
10	Dong Chil Chang, Il Chan Cho, Jong-Taek Suh, Su Jeong Kim, Yong Beom Lee. "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, 2011 Publication	1 %
11	media.neliti.com Internet Source	1 %

Exclude quotes	On	Exclude matches	< 1%
Exclude bibliography	On		