HYDROPONIC PRODUCTION OF LETTUCE (*Lactuca sativa* L.) IN A RECIRCULATING NUTRIENT FILM TECHNIQUE WITH IN-GROUND PASSIVE COOLING SYSTEM USING SELECTED GROWING MEDIA

JAN JAMES P. GRAZA

An Undergraduate Thesis Submitted to the Faculty of the Department of Agricultural and Biosystems Engineering, College of Engineering, Central Luzon State University, Science City of Muñoz, Nueva Ecija in Partial Fulfillment of the Requirements for the Degree of

BACHELOR OF SCIENCE IN AGRICULTURAL AND BIOSYSTEMS ENGINEERING
(Land and Water Resources Engineering)

JUNE 2019

ACCEPTANCE SHEET

This undergraduate thesis outline entitled, "**HYDROPONIC PRODUCTION OF LETTUCE (*Lactuca sativa* L.) IN A RECIRCULATING NUTRIENT FILM TECHNIQUE WITH IN-GROUND PASSIVE COOLING SYSTEM USING SELECTED GROWING MEDIA**", prepared and submitted by **JAN JAMES P. GRAZA,** in partial fulfilment of the requirements for the degree of **BACHELOR OF SCIENCE IN AGRICULTURAL AND BIOSYSTEMS ENGINEERING (Land and Water Resources Engineering),** is hereby approved:

RUEL G. PENEYRA
Member, Advisory Committee
6/14/19
Date Signed

VITALIANA U. MALAMUG
Member, Advisory Committee
06/14/19
Date Signed

CHITO F. SACE
Chairperson, Advisory Committee

6/14/19
Date Signed

Accepted in partial fulfillment of the requirements for the degree **BACHELOR OF SCIENCE IN AGRICULTURAL AND BIOSYSTEMS ENGINEERING (Land and Water Resources Engineering):**

MARVIN M. CINENSE
Chairperson, Department of Agricultural and Biosystems Engineering
6/14/19
Date Signed

VICTORINO T. TAYLAN
Dean, College of Engineering

6/14/19
Date Signed

BIOGRAPHICAL SKETCH

Jan James Pagatpatan Graza is the third-born child of Mr. Armando and Mrs. Adelaida P. Graza. He was born on the 22nd day of November 1997 and is currently living at Brgy. Malacañang, Sta. Rosa, Nueva Ecija. He author finished his primary education at Patalac Elementary School, Brgy. Patalac, Cabanatuan City, Nueva Ecija in 2010 and obtained first honors for six consecutive years. He obtained his secondary education diploma from the Nueva Ecija High School (NEHS) as third honorable mention in 2014.

After completing his secondary education, he entered Central Luzon State University and enrolled Bachelor of Science in Agricultural Engineering. As a college student, he invested his time in his studies and other extra-curricular activities. He was a college scholar during his first year and a Phildev scholar for four years. He became a member of the Lakas Angkan Student Organization in 2014. These organizations helped him in gain friends and developed interpersonal competency.

ACKNOWLEDGEMENT

This study has been made possible with the idea, knowledge, guidance, support and words of encouragement from the people who wholeheartedly lent their time, resources and efforts towards the completion of this research work. No words can express the author's gratitude to the following people who helped him in any possible way:

the Lord and Savior Jesus Christ, who is the primary source of knowledge, wisdom, guidance and favor which helped the researcher to finish this study, all glory is due Him;

Dr. Chito F. Sace for allowing the author to use the greenhouse and hydroponic set-up in the CLSU Hydroponics and Aquaponics Technology (CHAT). The researcher also would like to express his gratitude to him for being a good adviser, an inspiration, teacher and support for the success of the researcher;

Dr. Marvin M. Cinense and the rest of the DABE faculty and staff who also helped the researcher in the completion, supervision and conduct of this study;

Prof. Ruel G. Peneyra and Dr. Vitaliana U. Malamug, members of the Advisory Committee, for their wisdom, knowledge, patience, consideration, assistance, constructive criticisms and suggestions in improving the study.

Kuya Romeo, Kuya Joel, Kuya Marwin, Tatay Ben and Sir Jan Daves, the CLSU Hydroponics and Aquaponics Technology (CHAT) personnel and staff for their service and goodness in the conduct of the study and for acquiring the material other resources needed for the study;

the Graza family for their unparalleled and unequalled love and support especially during conduct of the study;

Kuya Carlo, Kuya DD, Kuya Prince, DJ, Ravin, Kuya Cedrick, Bill, Kuya Ben, Kuya Haj, Kuya Josh and other member of the Elisha Network (Cell Group) fot the encouragement and prayer during the conduct of the study;

Ate Hannah, Charie, and Kuya Je and the Lakas Angkan Ministry Inc. (LAMI) family for the spiritual advise and prayer during conduct of the study and the writing of paper;

To Pastor Erwin for being a good friend, leader and brother and CCFBC (Cabanatuan Community of Faith Baptist Church) family for their care and love in times of trials and challenges in life who always give an advice for the improvement of the author character and attitude;

Monette, Allyssa, Art, Claire, Renz, Cherish, Joana, Cherrie, and John Pio for helping the author in preparation of growing media, selection of the materials, and for measuring the height, width and weight of the crops during the conduct of the thesis;

The PhilDev (Philippine Development) Scholarship. To Maam, Zen, Maam Imee, and Maam Claudette and to the US donors who gives financial support and for listening to all of the story of the researcher during the conduct and conceptualization of the thesis;

Camille, for being an encouragement during the study and for being an inspiration; and

Lastly, to those people who weren't mentioned above, the researcher is forever grateful to all of you.

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ABSTRACT

GRAZA, JAN JAMES P., Department of Agricultural and Biosystems Engineering, Central Luzon State University, Science City of Muñoz, Nueva Ecija, Philippines, **JUNE 2019, HYDROPONIC PRODUCTION OF LETTUCE (*Lactuca sativa* L.) IN A RECIRCULATING NUTRIENT FILM TECHNIQUE WITH IN-GROUND PASSIVE COOLING SYSTEM USING SELECTED GROWING MEDIA.**

Adviser: CHITO F. SACE, Ph.D.

Hydroponic system in greenhouses is an innovation in the agricultural technology. It is a method in which plants may grow without the utilization of soil or soilless culture. Hydroponics is the great solution to develop an agriculture in the other country which lacks of arable lands. And by utilizing the in-ground cooling system to hydroponic production of lettuce, an alternative way of cooling has been done.

The study aimed to evaluate the performance of an existing in-ground passive cooling system (IGPCS) in lowering the nutrient solution temperature for lettuce production. The performance of the IGPCS system was compared with no nutrient cooling system. The study also determined the growth and yield of lettuce grown in different growing media.

The evaluated IGPCS was not able to attain the optimal temperature of the nutrient solution for growing lettuce. Results showed no significant difference on the resulting plant height, width, yield and water productivity between systems with and without IGPCS.

Results showed that the temperature differences in the two systems vary throughout the day but IGPCS was able to lower the temperature by 2-3° C at 2 pm. The average yield of lettuce planted on rice hull mixed with and without cooling system has higher yield compared to coco peat mixed.

Keywords: hydroponics; in-ground passive cooling; nutrient film technique

LITERATURE CITED

Al- Rahawy, M., Al- Rahawy, S., Al- Mulla, Y., and Nadaf, S. (2019). Influence of nutrient solution temperature on its oxygen level and growth, yield and quality of hydroponic cucumber. Canadian Center of Science and Education. *Journal of Agricultural Science*; 11(3),

Al-Khodmany K. (2018). The vertical farm: A review of developments and implications for the vertical city. Department of Urban Planning and Policy, College of Urban Planning and Public Affairs, University of Illinois, Chicago, Il 60607, USA.

Avrdc (2006). Vegetable Matter. Avrdc – The World Vegetable Center. Shanhua, Taiwan. From: Chito F. Sace, Jaypee H. Estigoy. Lettuce Production in A Recirculating Hydroponic System. *American Journal of Agricultural Science*. 2(5),196 -202.

Bar- Yosef B. (2008). Fertigation management and crops response to solution recycling in semi-closed greenhouses. Soilless Culture: Theory and Practice, 343-424.

Barbosa G., Gadelha F., Kublik N., Proctor A., Reichelm A., Weissinger E., Wohlleb G., And Halden R. (2015). Comparison of land, water, and energy requirements of lettuce grown using hydroponic vs. conventional agricultural methods. *International Journal of Environmental Research and Public Health.*

Beauchamp, E.G., & Torrancce, J.F. (1969). Temperature gradients within young maize plant stalks as influence by aerial and root zone temperature. Plant and Soil 30, 241-51.

Bloodnick E. (2018). Fundamentals of growing media. Retrieved on November 2, 2018 from https://www.pthorticulture.com/en/training-center/fundamentals-of-growing-media/.

Brechner, M. and Both, A. (2012). Hydroponic lettuce handbook. Cornell University CEA Program. Retrieve on May 18, 2019 from http://www.cornellcea.com.

Cedillo, I. (2017). The benefits of adding the water chiller to your hydroponic system. maximum yield. Retrieve on January 28, 2019 from https://www.maximumyield.com/the-benefits-of-adding-a-water-chiller-to-your-hydroponics-system/2/3228.

Chapman, E. (2018). What is the difference between geothermal open loop and closed loop? Retrieve on January 24, 2019 from https://haleymechanical.com/blog/geothermal-earth-loops/.

Commetti, N., Bremenkamp, D., Galon, K., Hell, L., and Zanotelli, M. (2013). Cooling and concentration of nutrient solution in hydroponic lettuce crop *Horticulura brasileria*. 31(2).

Commetti, N., Zanotelli, M. and Galon, K. (2013). Cooling and concentration of nutrient solution. Horticultura Brazileria 31, 287-292.

De Vries, I. (1997). Origin and domestication of *Lactuca sativa* L.. Genetic Resources Crop Evolution, 44,165–174.

Dodd, I.C., He, J., Turnbull, C.G.N., Lee, S.K., and Critchley, C. (2000). The influence of supra-optimal rootzone temperatures on growth and stomatal conductance in *Capcicuum annuum*, *Journal of Experimental Botany*, 51(343);239 – 248.

Eleouet, B., Ramage, M., and Rongier, G. (1990). Synthetic sponge-type articles having excellent water retention. Retrieved on December 1, 2018 from http://www.freepatentsonline.com/4957810.html.

Evans, M. and Hensley, D. (2004). Plants growth in plastic, peat, and processed poultry fiber growing container. *Horticultural Science*, 39 (5), 1012 -1014.

Giacomelli, G. (2018). What is hydrponics. The University of Arizona, Tucson Arizona. Retrieved on December 28, 2018 from http://ceac.arizona.edu/hydroponics.

Godfrey, S. (1996). An introduction to thermoelectric coolers. Retrieved on January 20, 2019 from https://www.electronics-cooling.com/1996/09/an-introduction-to-thermoelectric-coolers/#.

Grant A. (2018). Harvesting leaf lettuce: how and when to pick leaf lettuce. gardening knows how. Retrieved on January 30, 2019 from https://www.gardeningknowhow.com/edible/vegetables/lettuce/harvesting-leaf-lettuce.html.

Grow Guru (2013). How to grow fresh hydroponic lettuce. Retrieved on January 30, 2019 from https://growguru.co.za/blogs/hydroponic/how-to-grow-fresh-hydroponic-lettuce.

Harris, D. (1982). Hydroponics: gardening without soil. Centaur Publishers, Johannesburg, South Africa, 158 -179.

Hatfield, (2005). Radiation Balance. Retrieved on May 17, 2019 from https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/solar-radiation/.

Hatfield, J, L., Boote, K.J., Kimball, B.A., Ziska, L.H., and Wolfe, D.W. (2011). Climate impacts on agriculture: Implication for crop production. *Agronomy Journal*, 103, 351 – 370.

He J. and Lee, Sk. (1998). Growth and photosynthetic characteristics of lettuce (*Lactuca sativa* L.) grown under fluctuating hot ambient temperatures with the manipulation of cool root-zone temperature. *Journal of Plant Physiology*, 152, 387-391.

He, J. and Lee, S.K. (1998). Growth and photosynthetic characteristics of lettuce (*Lactuca sativa* L.) under fluctuation hot ambient temperatures with the manipulation of cool root-zone temperature. *Journal of Plant Physiology* 152: 387-391.

Hirasawa, S., Naktsuka, M., Masui, K., Kawanami, T. and Shirai, K. (2014). Temperature and humidity control in greenhouses in desert areas. Retrieved on November 21, 2018 from https://file.scirp.org/pdf/as_2014111621071357.pdf.

Hopper, E. (2014). Optimal nutrient reservoir parameters-understanding the heart of your system. maximum yield. Retrieved from https://www.maximumyield.com/optimal-nutrient-reservoir-parameters-understanding-the-heart-of-your-system/2/1143.

Li, H.G. And Wang, S.X. (2015). Technology and studies for greenhouse cooling. *World Journal of Engineering and Technology*, 3, 73-77.

Iannotti M. (2018). Why lettuce bolts and how to stop it. Retrieved on May 18, 2019 from https://www.thespruce.com/what-does-lettuce-bolt-do-1402981.

Jose, D. (2018). Lettuce production guide. Department of Agriculture Bureau of Plant Industry. Retrieved on January 29, 2019 from http://bpi.da.gov.ph/bpi/images/production_guide/pdf/lettuce.pdf.

Kaiser, C. and Ernst, M. (2017). Romaine lettuce. University of Kentucky, College of Agriculture, Food and Environment, Cooperative Extension Service. Retrieve on January 30, 2019 from http://www.uky.edu/ccd/sites/www.uky.edu.ccd/files/romaine.pdf.

Kim, H., Cho, Y., Kwon, O., Cho, M., Hwang, J., Jeon, W. and Bae, S. (2005). Effect of hydroponic solution pH on the growth of greenhouse rose. *Asian Journal of Plant and Sciences*, 4(1), 17-22.

Klaasen, P. (2018). Electrical conductivity, why it matters. Retrieved on November 2, 2018 from http://www.cannagardening.com/electrical-conductivity.

Kowalczyk, K. and Gajc-Wolska, J. (2011). Effect of the kind of growing medium and transplant grafting on cherry tomato yielding. Acta Scientiarum Polonorum. Hortorum Cultus = Ogrodnictwo. 10, 61-70.

Kumar, A., Tiwari, G.N., Kumar S. and Pandey, M. (2006). Research of greenhouse in agricultural engineering. *International Journal of Agricultural Research*, 1(4), 364-372.

Laliberte, K. (2018). How to grow salad greens all year. Retrieved on January 22, 2019 from https://www.gardeners.com/how-to/how-to-grow-salad-greens-all-year/7272.html.

Lallanilla M. (2018). What is the greenhouse effect? Retrieved on May 17, 2019 from https://www.livescience.com/37743-greenhouse-effect.html.

Levitt, J. (1980). Chilling, Freezing and High Temperature Stresses, Responses of Plants to Environmental Stress, London: Academic Press, 347 – 391.

Liscum, E., Askinosie, S., Leuchtman, D., Morrow, J., Willenburg, K. and Coats, D. (2014). Phototropism: Growing Towards an Understanding of Plant Movement. American Society of Plant Biologist. Retrieved on May 24, 2019 from http://www.plantcell.org/content/26/1/38.

Lykas, C. (2001). Nutrient solution management recirculating soilless culture of rose in mild winter climates. Acta Horticulture, 559(1), 543- 548.

Makendi, M. (2014). A comparative analysis of two plant growth mediums: hydroponic vs. soil. Retrieved on November 24, 2018 from https://www.paulding.k12.ga.us/cms/lib010/ga01903603/centricity/domain/540/biology%20research%20project%20exemplar%202014.pdf.

Marshall, K. (2017). How to grow plants in a rockwool. maximum yield. Retrieved on January 24, 2019 from https://www.maximumyield.com/stylin-stonewool/2/1272.

Mattson, N. (2016). Monitoring is crucial for growing lettuce and leafy greens year-round. Retrieved January 30, 2019 from https://hortamericas.com/blog/news/monitoring-is-crucial-for-growing-lettuce-and-leafy-greens-year-round/.

Michael, R. and Lieth, J. (2008). Soilless Culture: Theory and Practice. British Library Cataloguing in Publication Data. Street, Suite 1900, San Diego, Ca 92101-4495, Usa. Isbn: 978-0-444-52975-6.

Moon, J.H., Kang, Y.K. and Suh, H.D. (2007). Effect of root-zone cooling on the growth and yield of cucumber at supraoptimal air temperature. *Acta Horticultura*, 761, 271-274. Retrieved on January 22, 2019 from https://www.ishs.org/ishs-article/761_36.

Morgan, L. (2017). The convenience of hydroponic nutrient application systems. Retrieved on November 1, 2018 from https://www.maximumyield.com/the-convenience-of-hydroponic-nutrient-application-systems/2/3077.

Morgan, L., Hopper, E., Zeifman, Z., Bobcock, G., Cup, G. and Frog, T. (2018). Nutrient reservoir. Retrieved on November 30, 2018 from https://www.maximumyield.com/definition/3156/nutrient-reservoir.

Morgan, L. (2016). The micro revolution: growing hydroponic microgreen. maximum yield. nutrient reservoir. Retrieved November 1, 2018 from https://www.maximumyield.com/definition/3156/nutrient-reservoir.

Morgan, M. (2018). Nine most profitable plants to grow hydroponically. Retrieved on January 22, 2019 from https://www.igrow.news/news/9-most-profitable-plants-to-grow-hydroponically.

Nam, S.W., Kim, M.K. and Son, J.E. (1996). Nutrient solution cooling and its effect on temperature of leaf lettuce in hydroponic system. *Acta Horticultura*. Retrieved january 22, 2019 from https://www.ncbi.nlm.nih.gov/pubmed/11541574.

Nederhoff and Stanghellini. (2010). Practical hydroponics & greenhouses. Wageningen Ur Greenhouse Horticulture. Retrieved on October 29, 2018 from ISSN 1321-8727 - P. 52 - 59.

Pascual, C. (2018). Rootzone Cooling of Aeroponically-Grown Strawberry Plant (Fragaria X Annassa) Using Ground Heat Exchanger Under Tropical Greenhouse Condition. Central Luzon State University, Science City of Munoz, Nueva Ecija.

Pocock, G., Hardman, M. and Mackey, P. (2014). An introduction to hydroponic technology. Azocleantech. Retrieved on January 22, 2019 from https://www.azocleantech.com/article.aspx?articleid=492.

Popiel, C., Wojtkowiak, J., and Biernacka, B. (2001). Measurements of temperature distribution in ground. *Experimental Thermal and Fluid Science*, 25, 301- 309.

Rain, A. (2016). History of hydroponics. Retrieved on November 14, 2018 from http://www.rain.org/global-garden/hydroponics-history.html.

Rodriguez, T. (2018). An intensive organic lettuce farm in Cavite. Retrieved January 30, 2019 from http://agriculture.com.ph/2018/05/02/an-intensive-organic-lettuce-farm-in-cavite/.

Runkle, E. (2017). Vertical Farming. Michigan State University. Retrieved on November 1, 2018 from https://Www.Canr.Msu.Edu/People/Dr_Erik_Runkle.

Rusidy, A. (2019). Correlation between conductivity and total dissolved solid in various type of water: a review. iop conference series: earth and environmental science. Retrieved on May 16, 2019 from https://iopscience.iop.org/article/10.1088/1755-1315/118/1/012019/pdf.

Ryder, E. (1999). Lettuce, Endive and Chicory. Cabi, New York.

Sace, C. And Estigoy, J. (2015). Lettuce production in a recirculating hydroponic system. *American Journal of Agricultural Science*. 2(5), 196 -2012.

Sace, C.F and Agulto I.C. (2013). Water management for hydroponic honeydew melon production. Scholars Press Publishing, Av Akadmikerlag Gnbh &Co. Kg, Heinrich- Bocking- Str.6-8,66121, Saarbrucken, Germany.

Sace, C.F. (2008). Water Management System for Management Melon (*Cucumis melo* L.). Central Luzon State University, Science City of Munoz.

Salisbury, F.B. And Ross, C.W. (1992). Plant physiology. Wadsworth Publishing Company, California, U.S.A.

Sanders, D. (2001). Lettuce. Nc State Extension Publications. Retrieved on January from https://content.ces.ncsu.edu/lettuce

Sanders, J. (2016). Nutrient solution is important. Home hydro systems. Retrieved on January 28, 2019 from http://www.homehydrosystems .com/articles/nutrient%20solution%20temperature/nutrient%20solution%20temperature%20is%20important.html

Schwarz, M. (1967). Foam plastic a commercial growth medium. martinus nijhoff, The Hague/Kluwer Academic Publishers. 27(2), 289 – 29, Retrieve on December 1, 2018 from https://doi.org/10.1007/bf01373397.

Sharma, R. (2015). How to treat root rot for your hydroponics. Retrieved on May 16, 2019 from https://www.emeraldharvest.co/treat-root-rot-for-hydroponic-plants/.

Still, D. (2007). Lettuce. California State Polytechnic University, 3801 West Temple Avenue, Pomona, Ca 91768, USA. 5, 72-83.

Tehrane, P. (1995). International code of nomenclature for cultivated plants in 1995. regnum vegetable 133

Tellez, A., Liparakis, D., Santamouris, M. and Argiriou, A. (1992). Analysis of The Accuracy and Sensitivity of Eight Models to Predict the Performance of Earth-To-Air Heat Exchangers. T.E.I. Pireus And Laboratory of Meteorology, University of Athens.

Torres A., Mickelbart M., And Lopez R. (2010). Measuring ph and ec of large container crops. Retrieved on November 15, 2018 from https://www.canr.msu.edu/uploads/resources/pdfs/measuring_ph_and_ec_of_crops_grown_in_large_containers.pdf.

Treftz, C. and Omaye S. (2015). Comparison between hydroponic and soil systems for growing strawberries in a greenhouse. International Agricultural Extension. University of Nevada

Turner, B. (2018). How hydroponics works. Retrieved on October 31, 2018 from https://home.howstuffworks.com/lawn-garden/professional-landscaping/hydroponics1.htm

Viswavidyalaya, B. (2012). Soil-less culture and modern agriculture. *World Journal of Science and Technology*. ISSN: 2231 – 2587.