

**FRILLICE LETTUCE (*Lactuca sativa* L.) PRODUCTION USING
THERMO-ELECTRIC COOLER FOR RECIRCULATING
AEROPONIC SYSTEM**

ALYSSA MAE E. MAMUNGAY

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, Philippines in
Partial Fulfillment of the Requirements for the Degree

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

JUNE 2019

ACCEPTANCE SHEET

This undergraduate thesis entitled **FRILLICE LETTUCE (*Lactuca sativa* L.) PRODUCTION USING THERMOELECTRIC COOLER FOR RECIRCULATING AEROPONIC SYSTEM** prepared and submitted by **ALYSSA MAE E. MAMUNGAY** as partial fulfillment of the requirements for the degree **BACHELOR OF SCIENCE IN AGRICULTURAL AND BIOSYSTEMS ENGINEERING (Land and Water Resources Engineering)**, is hereby accepted:


THEODY B. SAYCO, Ph. D.
Member, Advisory Committee

6/14/19

Date Signed


VITALIANA U. MATAMUG, Ph.D.
Member, Advisory Committee

6/14/19

Date Signed


CHITO F. SACE, Ph.D.
Chairperson, Advisory Committee

6/13/19

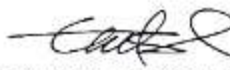
Date Signed

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, Ph.D.
Chairperson, Department of Agricultural and Biosystems Engineering

6/14/19

Date Signed


VICTORINO T. TAYLAN, Ph.D.
Dean, College of Engineering

6/14/19

Date Signed

BIOGRAPHICAL SKETCH

The author, Alyssa Mae E. Mamungay, the eldest daughter of Mr. Roland B. Mamungay and Mrs. Amelia E. Mamungay, was born on December 12, 1997 in San Jose, Occidental Mindoro and she is currently living in San Jose City, Nueva Ecija.

She took her primary education at Murtha Central School, where she was a consistent honor student. At the age of eight, she started joining District and Division Science Quiz Bee and managed to bring home medals and certificates that count as her achievements.

After graduation in 2010, she entered San Jose National Agricultural and Industrial High School (SJNAIHS) to continue her secondary education. During her secondary level, she managed to balance her academics and extracurricular activities. The author is not only academically inclined but is also good in other fields, such as sports and arts. In the four years she spent in high school, she became the president of the Science Club, auditor of the Supreme Student Government, and feature editor of the school paper. She graduated on 2014 and received an Excellence in Science Award, Leadership Award, Athlete of the Year, Outstanding Student in Technical Vocational Education (TVE) and Girl Scout of the Year.

She took the CLSU College Admission Test (CLSU-CAT) and fortunately passed and got admitted at the Central Luzon State University. She enrolled in the College of Engineering with the degree Bachelor of Science in Agricultural and Biosystems Engineering major in Land and Water Resource Engineering

Aside from academics, she also engaged in extracurricular activities. She joined the Badminton Team of the College of Engineering during her first year but later became

a varsity athlete of the CLSU Women's Futsal Team. She is also a member of the CLSU Sigma Beta Sorority, a non-college based organization. Despite being a varsity athlete and a member of an organization, she still managed to fulfill her duties and responsibilities as a student.

ACKNOWLEDGMENT

The preparation and completion of this study was made possible with the guidance and help of several individuals who in one way or another contributed and extended their valuable assistance. Their contributions are sincerely appreciated and gratefully acknowledged. However, she would like to express profound appreciation and indebtedness particularly to the following:

Dr. Chito F. Sace, who gave the idea of this study and for his unfailing guidance and support throughout the completion of this study as the Chair of the Advisory Committee;

The supportive members of the advisory committee, Dr. Vitaliana U. Malamug and Dr. Theody B. Sayco, for their professional advice, constructive comments and suggestions for the completion of this study;

Dr. Marvin M. Cinense, Chairperson of the Department of Agricultural and Biosystems Engineering and the rest of the DABE faculty and staffs, for the knowledge they shared and for giving so much considerations;

the CLSU-Hydroponics and Aquaponics Technology (CHAT) team, headed by Dr. Chito F. Sace, for allowing this study to be conducted in the premises of CHAT demonstration farm and experimentation station;

Sir Dave, Kuya Tisoy, Kuya John Dec, Tatay and Nanay of CHAT, Kuya Romie, for willingly helping her during the entire duration of the study;

the CLSU Institute of Sports, Physical Education and Recreation, headed by Sir Bienvenido S. Kanapi, for the scholarship grant and all the privileges she get to enjoy as a varsity athlete.

her Futsal family and her coach Felody D. Santiago, for their big contribution in her college journey, as stress-relievers and for molding the author the way she is today;

Claire, Cherish, Renz, Joana, Ron, Tony, Dan and to her batches Kenneth, Linesey, Jasmin, Jeff, Lira, and Dominic, for being her support system throughout her college years and as sources of laughters and tears and for being there during her best and darkest days;

Tita Alma, Paupau, Pia and Aliah, for the kindness, help and encouragement to finish this study;

Kuya Rod, Ate Kat, Kiat, Inigo and Brel, for their warm love and support, for always making her feel at home and making her part of their family and to all of the kindness and help throughout her college days.

Mr. Roland B. Mamungay and Mrs. Amelia E. Mamungay, her parents, and to her brothers Justin and Arris, for serving as inspiration and bliss every step of the way and for the unconditional love and support;

relatives, friends and others who are not mentioned for sharing their support, either morally, financially and physically; and,

above all, to the Great Almighty, the Author of knowledge and wisdom, for blessing her life and for giving her the strength and courage despite the obstacles in the completion of this piece of work.

TABLE OF CONTENTS

	PAGE
LIST OF TABLES	x
LIST OF FIGURES	xi
LIST OF APPENDIX TABLES	xii
LIST OF APPENDIX FIGURES	xiii
ABSTRACT	xv
INTRODUCTION	1
Background of the Study	1
Statement of the Problem	3
Significance of the Study	4
Objectives of the Study	4
Scope and Limitation of the Study	5
Time and Place of the Study	5
REVIEW OF LITERATURE	6
Lettuce Production	6
Frillice Lettuce	6
Crop Requirements	7
Seedling Propagation and Harvesting	7
Aeroponics Technology	7
Concept of Aeroponics	8
Types of Aeroponics	9
Low-pressure Aeroponic System	9
High-pressure Aeroponic System	10
Commercial Aeroponic System	10
Advantages of Aeroponic System	11
Disadvantages of Aeroponic System	12
Soilless Culture	12
Growing Media	13
Cocopeat	13
Rice Hull and Carbonized Rice Hull	14
Sand	14
The Nutrient Solution	15
Air and Nutrient Solution	16

Water and Nutrient Solution	16
Monitoring the Nutrient Solution	16
pH and Electrical Conductivity	17
Temperature	17
Nutrient Solution Management	18
The Greenhouse Structure	18
 METHODODOLOGY	 20
Conceptualization of the Study	20
Materials and Instruments	21
Recirculating Aeroponic System	22
Growing Media and Plastic cups	25
Cultural Practices	26
Media Preparation, Seed Planting and Growing	26
Nutrient Solution Management	27
Pest Management	28
System Maintenance	28
Harvesting	28
Experimental Design and Layout	28
Data Gathered	30
Environmental Parameters	30
Temperature	30
Relative Humidity	30
Water Quality Parameters	31
Temperature	31
pH	31
Total Dissolved Solids	31
Agronomic Parameters	32
Plant Height	32
Number of Leaves	32
Root Mass	32
Weight of Produce	33
Water Consumption	33
Water Productivity	33
Statistical Analysis	33
 RESULTS AND DISCUSSION	 34
Environmental Parameters	34
Temperature	35
Relative Humidity	36
Water Quality Parameters	37
pH	37
Total Dissolved Solids	38
Nutrient Solution Temperature	39

LIST OF FIGURES

FIGURE		PAGE
1	Conceptual framework	21
2	Front and top view of the recirculating aeroponic system	24
3	Thermo-electric cooler assembly	24
4	Rice hull mixture	25
5	Cocopeat mixture	25
6	Seed planting	26
7	Insertion of growing cups	27
8	Nutrient solution management	27
9	Experimental layout	29
10	Daily temperature inside and outside of the greenhouse	35
11	Daily change of relative humidity	36
12	Daily recorded pH	37
13	Daily TDS level during production	39
14	Temperature of the nutrient solution inside the reservoir	40
15	Temperature of the nutrient solution inside the growing chamber	41
16	Water consumption in weekly interval	47

LIST OF APPENDIX TABLES

APPENDIX TABLE		PAGE
1	Analysis of variance on plant height	59
2	Analysis of variance on number of leaves	59
3	Analysis of variance on root mass	59
4	Analysis of variance on weight of produce	60
5	Daily temperature inside and outside of the greenhouse	61
6	Daily relative humidity inside and outside the greenhouse	62
7	Daily pH level of the nutrient solution	63
8	Daily total dissolved solids (ppm) of the nutrient solution	64
9	Daily temperature of the nutrient solution inside the reservoir	65
10	Daily temperature of the nutrient solution inside the growing chamber	66
11	Root mass (g) gained by lettuce after harvesting	67
12	Weight of produce (g) gained after harvesting	68
13	Daily water consumption	69
14	Plant height of lettuce in RAS with and without TEC	70
15	Number of leaves of lettuce grown in RAS with and without TEC	71

LIST OF APPENDIX FIGURES

APPENDIX FIGURE		PAGE
1	Parts of the RAS	72
2	Installation of the pump into the system	72
3	Installed peltier thermo-electric cooler	73
4	Thermo-electric cooler assembly	73
5	Plastic cups as growing cups	74
6	Preparation of the growing media	74
7	The lettuce seeds	75
8	Installation of the growing media into the holes	75
9	The nutrient solution	76
10	TDS/EC and pII meter	76
11	Measuring pH and TDS/EC	77
12	Thermo-hygrometer	77
13	The timer switch	78
14	Weighing scale	78
15	Aeroponic frillice lettuce production (1 st week)	79
16	Aeroponic frillice lettuce production (3 rd week)	79
17	Aeroponic frillice lettuce production (4 th week)	80
18	Plant height measurement	80
19	Harvesting of lettuce (5 th week)	81
20	Harvested frillice lettuce	81

ABSTRACT

MAMUNGAY, ALYSSA MAE ESGUERRA, Department of Agricultural and Biosystems Engineering, Central Luzon State University, Science City of Muñoz, Nueva Ecija, **June 2019, FRILLICE LETTUCE (*Lactuca sativa* L.) PRODUCTION USING THERMO-ELECTRIC COOLER FOR RECIRCULATING AEROPONIC SYSTEM.**

Adviser: CHITO F. SACE, Ph.D.

The study was conducted to evaluate the growth and yield of frillice lettuce using thermo-electric cooler (TEC) for recirculating aeroponic system (RAS) and to compare it with the growth and yield of frillice lettuce grown in RAS without TEC; and to determine the water consumption and productivity of frillice lettuce under RAS.

The growing cups filled with the growing media and lettuce seeds were randomly inserted in two RAS following the statistical design and layout.

Environmental and water quality parameters together with agronomic parameters (plant height, number of leaves, root mass, weight of produce, water consumption and water productivity) of plant were recorded to determine the response of lettuce. The study was laid out using the 2x2x4 factorial in CRD (Completely Randomized Design) with cooling method (Factor A) and growing media (Factor B). The data gathered were analyzed using ANOVA.

Frillice lettuce in RAS with TEC gave a much taller plant height with 19.25 cm compared to 18.05 cm mean height of plant subjected to RAS without TEC. In terms of leaves, RAS with TEC were numerous with a mean value of 16 leaves and 14 leaves for RAS without TEC. Root mass under RAS with TEC has 4.30 grams/plant and 3.90 grams/plant for RAS without TEC. The weight produce in RAS with TEC was higher

having 6.15 grams/plant while 4.85 grams/plant for RAS without TEC. Lettuce grown in RAS with TEC consumed 51.67 liters of water while for lettuce grown in RAS without TEC consumed 52.93 liters of water. The water productivity of frillice lettuce obtained a mean value of 32.24 g/L in RAS with TEC and 24.32 g/L in RAS without TEC.

LITERATURE CITED

- AESSENSE, A. 2012. Understanding water quality, water EC and pH. Retrieved on May 28, 2019 from <http://cdn2.hubspot.net/hubf/Understanding-Water-Quality-pH.pdf>
- ALEXANDRATRS, N. and BRUINSMA, J. 2012. World agriculture towards 2030/2030. The 2012 revision. Global perspective Studies. FAO, ESA Working Paper No. 12-03. Retrieved on October 27, 2018 from www.fao.org/economics/esa.
- AWANG, Y., MOHAMAD, R., SIIASHAROM, A.S., SELAMAT, A. 2009. Chemical and physical characteristics of cocopeat-based media mixtures and their effects on the growth and development of celosia cristata. Department of Crop Science, Faculty of Agriculture, University of Putra Malaysia, Serdang, Selangor, Malaysia. American Journal of Agricultural and Biological Sciences, Science Publications. Retrieved on March 2, 2019 from <http://www.researchgate.net>.
- BAILEY, D.A. and NELSON, P.V. 2012. Designing a greenhouse crop fertilization program. North Carolina State University. Depart of Horti Sci. Retrieved on October, 018 from www.ces.ncsu.edu/depts/hort/floriculture/plugs/pertprog.pdf.
- BARAK, P., SMITH, J.D., KRUEGER, A.R., PETERSON, L.A. 1996 Measurement of short-term nutrient uptake rates in cranberry by aeroponics. *plant cell and enviro.* 19:237-242.
- BARKER, B.T.P. 1992. Long Ashton research station annual report: Studies on root development.
- BLIESNER, R.D., DARGHOUTH, M.S., HANNEMAN, M., GOHRING, T. 2005. Implications of irrigated agriculture with growing water scarcity, increasing food requirements, environmental sustainability, and changing climate panel presentation. World water and environmental resources congress; Anchorage, Alaska, United States. Retrieved on November 21, 2018 from [http://dx.doi.org/10/1016/40792\(173\)539](http://dx.doi.org/10/1016/40792(173)539)
- BUER, C.S., CORELL, M.J., SMITH, T.C., TOWLER, M.J., WEATHERS, P.J., NADLER, M., SEAMAN, J., WALCERZ, D. 1996. Development of non-toxic acoustic window nutrient-mist biore-actor and relevant growth data in vitro cell. *Dev Biol-Plant.* 32:299-304. Retrieved on November 22, 2018 from <https://doi.org/1007/BF02822703>.
- BUTLER, J.D., OEBKER, N.F., 2006. Hydroponics as a hobby- growing plants without a soil. Circular 844. Urbana (IL 61801): Information Office, College of Agriculture, University of Illinois.

- BUTTAR, A., CHANDIO, F.A., GAO, J., LAKHIAR, I.A., SYED, T.N. 2018. Modern plant cultivation technologies in agriculture undercontrolled environment: A review aeroponics. *Journal of Interactions*, 13:1,338-352, DOI:10.1080/174295.2018.1472308. Retrieved on November 10, 2018 from <http://doi.org/10.1080/174295.2018.1472308>
- CARBONEL, E. 2018. Passive hydroponic system for peppermint (*Mentha x Piperita*) production using different growing media. College of Engineering, Department of Agricultural and Biosystems Engineering, Central Luzon State University.
- COLOMA, D. 2018. Aeroponic system for basil production. College of Engineering, Department of Agricultural and Biosystems Engineering, Central Luzon State University.
- COX, D.A. 2008. Organic growing media and fertilizers for greenhouses. Retrieved on March 2, 2019 from <http://ag.umass.edu>.
- DE LEON, T. and TAGUINOD, A. 2005. Rice and carbonized rice hull. *Rice Bulletin Series No. 47*. Philippines Rice Research Institute. Retrieved on March 2, 2019 from <http://www.edoc.site/-carbonized-rice-hull-pdf-free.html>.
- EDISON, P. 2016. Advantages and disadvantages of cocopeat. Retrieved on March 2, 2016 from <http://www.coco-peat.com>.
- ENGENHART, M. 1984. The influence of lead ions on productivity and mineral balance of *Phaseolus-vulgaris* in hydroponics and aeroponics. *Flora*.175:273-282.
- FENANGAD, D. 2018. Controlled environment condition in an indoor farming system for romaine lettuce production. Central Luzon State University, Science City of Muñoz, Nueva Ecija.
- GUANG-JAE, L., BO-GOO, K., K. TAE-IL, K. TAE-JUNG, K., JIN-HAN, K. 2007. Tomato hydroponics in Korea. *Fruit, Vegetables and Cereal Science and Biotechnology*. 1(2):104-109
- HATFIELD, J.L. and PRUEGER, J.H. 2015. Temperature extremes: effect on plant growth and development. *Weather and Climate Extremes*. 10:4-10. Retrieved on October 17, 2018 from <https://doi.org/10.1016>.
- HUSSAIN, A. 2014. Review on the science of growing crops without soil (Soiless culture)- A Novel Alternative For Growing Crops. *International Journal of Agriculture and Crop Sciences*. Available online at www.ijagcs.com IJACS/2014/7-11/833-842 ISSN 2227-670X, 2014 IJACS Journal.

- BUTTAR, A., CHANDIO, F.A., GAO, J., LAKHIAR, I.A., SYED, T.N. 2018. Modern plant cultivation technologies in agriculture undercontrolled environment: A review aeroponics, *Journal of Interactions*, 13:1,338-352, DOI:10.1080/174295.2018.1472308. Retrieved on November 10, 2018 from <http://doi.org/10.1080/174295.2018.1472308>
- CARBONEL, F. 2018. Passive hydroponic system for peppermint (*Mentha x Piperita*) production using different growing media. College of Engineering, Department of Agricultural and Biosystems Engineering, Central Luzon State University.
- COLOMA, D. 2018. Aeroponic system for basil production. College of Engineering, Department of Agricultural and Biosystems Engineering, Central Luzon State University.
- COX, D.A. 2008. Organic growing media and fertilizers for greenhouses. Retrieved on March 2, 2019 from <http://ag.umass.edu>.
- DE LEON, T. and TAGUINOD, A. 2005. Rice and carbonized rice hull. Rice Bulletin Series No. 47. Philippines Rice Research Institute. Retrieved on March 2, 2019 from <http://www.edoc.site/-carbonized-rice-hull-pdf-free.html>.
- EDISON, P. 2016. Advantages and disadvantages of cocopeat. Retrieved on March 2, 2016 from <http://www.coco-peat.com>.
- ENGENHART, M. 1984. The influence of lead ions on productivity and mineral balance of *Phaseolus-vulgaris* in hydroponics and aeroponics. *Flora*.175:273-282.
- FENANGAD, D. 2018. Controlled environment condition in an indoor farming system for romaine lettuce production. Central Luzon State University, Science City of Muñoz, Nueva Ecija.
- GUANG-JAE, L., BO-GOO, K., K. TAE-IL, K. TAE-JUNG, K., JIN-HAN, K. 2007. Tomato hydroponics in Korea. *Fruit, Vegetables and Cereal Science and Biotechnology*. 1(2):104-109
- HATFIELD, J.L. and PRUEGER, J.H. 2015. Temperature extremes: effect on plant growth and development. *Weath and Clim Extre*. 10:4-10. Retrieved on October, 17, 2018 from <https://doi.org/10.1016>.
- HUSSAIN, A. 2014. Review on the science of growing crops without soil (Soiless culture)- A Novel Alternative For Growing Crops. *International Journal of Agriculture and Crop Sciences*. Available online at www.ijagcs.com IJACS/2014/7-11/833-842 ISSN 2227-670X, 2014 IJACS Journal.

- JOSE, D. 2016. Lettuce production guide. Department of Agriculture, Bureau of Plant Industry. Retrieved on January 16, 2019 from <http://www.bpi.da.gov.ph>.
- KOCHIAN, L.V. 2000. Molecular physiology of mineral nutrient acquisition transport, and utilization. In: Buchanan B, Gruissem W, Jones R, editors. Biochemistry and molecular biology of plants. Am Soci of Plant Physi, Rockville MD; p. 1204-1249.
- MANI, P. 2016. Design modeling and simulation of a thermoelectric cooling system (TEC). Retrieved on February 5, 2019 from <http://schoolworks.wmich.edu>.
- MARK, E. 2016. Temperature and humidity. Retrieved on May 25, 2019 from <https://www.thehealingcanna.com/growroom-temperature-humidity>
- MARTI-LAURENT, F., THAM, F.Y., LEE S.K., HIE, J., DIEM, H.G. 2000. Field assessment of aeroponically grown and nodulated acacia mangium. Retrieved on October 27, 2019 from <https://doi.org/>
- MBIYU, M. W., J. MUTHONI, J., KABIRA, J., ELMAR, G., MUCHIRA, C., PWAIWAI, P., NGARIYA, J., OTIENO, S., ONDITI, J., 2012. Use of aeroponics technique for potato (*solanum tubersum*) minitubers production in Kenya. J of Horti and Fore. 4:172-177. Retrieved on October 13, 2018 from <https://dx.doi.org/10.5897>
- MIXPH. 2015. Lettuce production guide with return of investment (ROI). Retrieved on January 12, 2019 from <http://www.mixph.com/lettuce-production-guide-with-return-of-investment-roi/>.
- NASA, SPINOFF. 2006. Progressive plant growing has business blooming. In: Environmental and Agricultural Resources. New York: NASA, Spinoff; p. 64-77.
- NIR, I. 1982. Growing plants in aeroponics growth system. Acta Hort. 126:435-448. Retrieved on December 19, 2018 from <https://doi.org/10.17660/ActaHortic>
- OSVALD, J., PETROVIC, N., DEMSAR, J. 2001. Sugar and organic acid content of tomato fruits (*lycopersicon lycopersicum mill.*) grown on aeroponics at different plant density. Acta Alimentaria. 30(1):53-61.
- OTAZU, V. 2014. Manual on quality seed potato production using aeroponics. Lima (Peru): International Potato Center (CIP); p.44. Retrieved from <http://cippotato.org.research/publication/manual-on-quality-seed-potato-production-using-aeroponic>
- PETERSON, L.A. and KRUEGER, A.R. 1988. An interminttent aeroponic system. Crop Sci. 28:712-713. Retrieved on November 10, 2018 from <http://dx.doi.org/>

- POPP, J., LANKER, Z., HARANGIRAKOS, M., FARI, M. 2014. The effect of bioenergy expansion: Food, Energy, and Environment. *Renew Sust EnerRev*.32:559578. Retrieved on October 17, 2018 from <http://dx.doi.org/>.
- PROFESIONAL SECRETS. 2018. Lettuce guide, Frillice lettuce. Retrieved on January 25, 2019 from <http://www.professionalsecrets.com/lettuce-guide-frillice-lettuce>.
- PUAL, C. 2000. Heath and hydroponics. *Practical hydroponic and Greenhouse*. 53:28-30.
- RESH, H.M. 2004. Hydroponic food production. Mahwah (NJ, USA):Newconcept Press, Inc. ISBN-10:093123199X.
- ROLOT, J.L., SEUTIN, H., MICHELANTE, D. 2002. Production de minitubercules de pomme de terre par hydroponie; evaluation d'un systemecombinant les techniques "NFT" et "gravel culture" pour deux types de solutions nutritives. *Biotec Agr Soc Env*. 6:155-161.
- SACE, C.F. 2015. Hydroponics. Retrieved on October 27, 2018 from Smart Farming Techniques Series No. 1: Smart Farming Systems Addressing Water, Food and Energy.
- SACE, C.F. and AGULTO, I.C. 2013. Water management for hydroponics honeydew melon production (ISBN 978-3-639-51691-3), 2013 Scholars Press Publishing, AV Akademikerlag gmbH& Co. KG, Heinrich-Bocking-Str. 6-8, 66121, Saarbrücken, Germany.
- SACE, C.F. and ESTIGOY, J.H. 2015. Lettuce production in a recirculating hydroponic system. *American Journal of Agricultural Science*. Vol. 2, pp, 196-202.
- SACE, C.F and NATTVIDAD, P.E. JR. 2015. Economic analysis of an urban vertical garden for hydroponic production of lettuce (*Lactuca sativa*)*, *International Journal of Contemporary Applied Sciences* Vol. 2, No. 7, July 2015 (ISSN:2308-1365) Retrieved from (ISSN:2308-1365).
- SARDARE, M.D. and ADMANE, S.V. 2013. A review on plant without soil -hydroponic *IJRET*. 2:229-304.
- SELA, G. 2017. Water requirements of crop. Retrieved on November 22, 2019 from <http://www.smart-fertilizer.com/articles/water-requirements-of-crops>.
- SHEARD, R. W. 1991. Sand, silt and clay. Retrieved on March 2, 2019 from <http://archive.lib.msu.edu/tic/stnew/article/1991sep4.pdf>.

- SIDDAHARTH, F. 2017. Aeroponics. Retrieved on November 21, 2018 from <http://www.Academia.edu>.
- SINGER, S. 2010. Basil herb. Denton Country. Texas, USA.
- SONNEVELD, C. and VOOGT, W. 2009. Plant nutrition of greenhouse crops. New York (USA): Springer. ISBN 9048125316.
- STONER, R.J. 1983. Aeroponics versus bed and hydroponic propagation. Florists Review.
- STEINER, A.A. 1968. Soilless culture. Proceedings of the IPI 1968 6th colloquium of International Potash Institute Florence, Italy, p.324-341.
- TAIZ, L. and ZEIGER, E. 1998. Plant physiology. Sunderland (MA, USA): Sinauer Associates, Inc. Publishers. ISBN: 0878938311.
- ZIEGLER, R. 2015. The Vertical aeroponic growing system. Reinhold Ziegler International Inc. P.O. Box 3171 Sausalito, CA 94996 U.S.A. Retrieved on November 15, 2018 from <http://www.synergyii.com>
- ZSOLDOS, F., VASHEGYI, A., ERDEI, L. 1987. Lack of active K⁺ uptake in aeroponically grown wheat seedlings. *Physiol Plant.* 71:359-364.