

**EVALUATION OF VERMICOMPOST TEA IN FOGPONICS SYSTEM WITH
INTEGRATION OF INTERNET OF THINGS FOR CHINESE KALE
(*Brassica oleracea*) PRODUCTION**

KENNETH T. EVANGELISTA

An Undergraduate Thesis Manuscript 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 of

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

JULY 2024


ACCEPTANCE SHEET

This undergraduate thesis entitled “EVALUATION OF VERMICOMPOST TEA IN FOGPONICS SYSTEM WITH INTEGRATION OF INTERNET OF THINGS FOR CHINESE KALE (*Brassica oleracea*) PRODUCTION” prepared and submitted by **KENNETH T. EVANGELISTA**, in partial fulfillment of the requirements for the degree of **BACHELOR OF SCIENCE IN AGRICULTURAL AND BIOSYSTEMS ENGINEERING (MAJOR IN LAND AND WATER RESOURCES ENGINEERING)** is hereby accepted:


MARVIN M. CENENSE, Ph.D.
Member, Advisory Committee

5/28/2024

Date Signed


JOHN VINCENT A. NATE, M.Sc
Member, Advisory Committee

5/28/2024

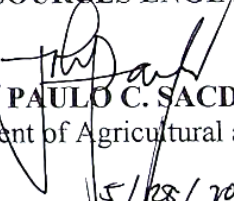
Date Signed


JOHN PAULO C. SACDALAN, Ph.D.
Chair, Advisory Committee

5/28/2024

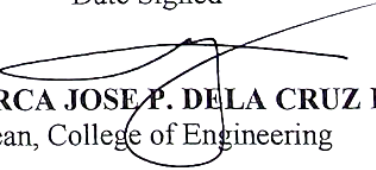
Date Signed

Accepted as partial fulfillment of the requirements for the degree of **BACHELOR OF SCIENCE IN AGRICULTURAL AND BIOSYSTEMS ENGINEERING MAJOR IN LAND AND WATER RESOURCES ENGINEERING:**


JOHN PAULO C. SACDALAN, Ph.D.
OIC Head, Department of Agricultural and Biosystems Engineering

5/28/2024

Date Signed


ROY SEARCA JOSE P. DELA CRUZ Ph.D.
Dean, College of Engineering

5/28/2024

Date Signed

BIOGRAPHICAL SKETCH

The author, Mr. Kenneth T. Evangelista, was born and raised in Cabanatuan City Nueva Ecija. Born on the 25th of June in the year 2002, he enjoys the company of his 2 younger brothers and the warm and loving comfort of his parents Mr. Kevin D. Evangelista who is originally from Lipa City, Batangas, and Mrs. Melanie T. Evangelista who resides in Cabanatuan City, Nueva Ecija. Presently, the author is residing in Cabanatuan City, Nueva Ecija.

The author finished his elementary education at the Cabanatuan Confucius School in 2013, and his secondary education at the Honorato C. Perez Sr. Memorial Science High School in 2020. Currently, he is a fourth-year student at the Central Luzon State University pursuing a bachelor's degree in Agricultural and Biosystems Engineering looking to successfully complete his Tertiary Education in July this year.

Taking up a degree that relates to agriculture has long been an interest of the author due to having a family lineage involved in farming. In time, the degree has become less of an aspiration, but a commitment to serve and be of any aid to salvage the ailing sector of agriculture in the Philippines. Finishing a program this competitive would take a lot from the students, thus, the author intends to keep his focus on the goal— finishing the program in time, and in style. With the help of everyone around him, he expects to make the remaining time of his stay in the university meaningful all the while being memorable.

ACKNOWLEDGMENT

First and foremost, the author expresses his gratitude and appreciation to Almighty God for bestowing His abundant blessings upon him during his tenure at the Central Luzon State University, and for allowing him to complete this study safely and triumphantly in pursuit of acquiring greater knowledge.

The author would also like to express his deep and sincere appreciation to his thesis adviser, Dr. John Paulo C. Sacdalan of the Department of Agricultural and Biosystems Engineering, College of Engineering, for allowing him to foster new sets of knowledge by exposing him to new experiences to bolster his commitment to the program. His energy, foresight, genuineness, and drive have profoundly motivated the author. Having the opportunity to pursue studies under his mentorship was a tremendous privilege and source of pride. The author is immensely thankful for all that he has bestowed upon him.

To the esteemed members of the Advisory Committee, Dr. Marvin M. Cinense and Engr. John Vincent A. Nate, for their technical support and for providing insightful suggestions for the betterment of this study.

To Dr. Theody B. Sayco and Dr. Claire M. Castillo, Dean of the College of Engineering, and the Faculty-In-Charge in the CLSU Hydroponics and Aquaponics Technology (CHAT), respectively, for their trust and assistance to the author in conducting the study within the CHAT's premises.

To Mr. Kevin D. Evangelista and Mrs. Melanie T. Evangelista – the author's parents, and his siblings, for being his stronghold – a support system which has given him strength in trying times. They have motivated the author in many ways one could have ever imagined. The author takes all the support and encouragement dearly.

To Deiciree Del Valle, Engela Venice Factuar, the author's primary companion throughout the duration of this study, for their unwavering support, help, motivation, and guidance on this study's journey.

Ultimately, the author extends his sincerest gratitude to all individuals who have provided direct or indirect support that enabled him to successfully complete this study.

TABLE OF CONTENTS

	PAGE
LIST OF TABLES	ix
LIST OF FIGURES	x
LIST OF APPENDICES	xii
LIST OF APPENDIX TABLES	xii
LIST OF APPENDIX FIGURES	xiv
ABSTRACT	xvi
INTRODUCTION	1
Background of the Study	1
Statement of the Problem	4
Objectives of the Study	5
Significance of the Study	5
Scope and Limitation of the Study	7
Time and Place of the Study	7
REVIEW OF LITERATURE	8
Chinese Kale	8
Vermicompost Tea	11
Greenhouse Farming	13
Fogponics System	15
Set-up of the Fogponics System	19
Internet of Things (IoT)	19
Cost Analysis	21
METHODOLOGY	24
Conceptual Framework	24
Materials	25
Design of the Fogponics System	30
The Greenhouse	30
The Fogponics System	31
The Automation of the System and Structure	33

	PAGE
Flowchart of the fogponics system's automation	34
Block Diagram of the System	36
Cultural Practices	38
Seedlings	38
Transplanting	38
Harvesting	38
Fogging Frequency	39
Temperature and Humidity	39
Experimental Design	39
Experimental Layout	40
Data Analysis	42
Data to be Gathered	42
Growth of the Plant	42
Lead Length	43
Leaf Width	43
Number of Leaves	43
Plant Height	43
Root Length	43
Yield Weight	44
Nutrient Solution	44
Ambient Temperature and Humidity	46
Water Temperature	46
Water Consumption	46
RESULTS AND DISCUSSION	47
Greenhouse Description and Specification	47
Weather conditions of the Greenhouse	48
Water Consumption of the Sprinkler System	49
Automated Fogponics system for Chinese kale production	50
Analysis of vermicompost tea	52
Water Quality Parameters	52
TDS and pH Level monitoring	52
Nutrient Solution Temperature monitoring	55
Electrical Conductivity Monitoring	57
Nutrient Solution Level monitoring	58
Growth and Yield Parameters	60

	PAGE
Plant Height	60
Leaf Length	63
Leaf Width	65
Number of Leaves	67
Root Length	69
Yield Weight	71
Water Productivity	73
Simple Cost Analysis	74
Billing of Materials	76
SUMMARY, CONCLUSION, AND RECOMMENDATIONS	77
Summary	78
Conclusions	80
Recommendations	82
LITERATURE CITED	83
APPENDICES	99
Appendix Tables	100
Appendix Figures	106

LIST OF TABLES

TABLE		PAGE
1	Materials needed for the study	25
2	Analysis of the nutrient solution	52
3	Average plant height	61
4	Average leaf length	64
5	Average width of leaves	66
6	Average number of leaves	67
7	Root length	70
8	Yield weight	71
9	Water Productivity of the fogponics and hydroponics systems	74
10	Cost Analysis	75
11	Cost comparison between fogponics and hydroponics systems	76

LIST OF FIGURES

FIGURE		PAGE
1	Conceptual framework of the study	24
2	Perspective of the fogponics system	31
3	Cross-section view of the gallon reservoirs	32
4	Perspective view of the fogponics system	33
5	Flowchart of the system	35
6	Block Diagram of the system	37
7	Wiring legends used in the block diagram of the system	37
8	Experimental layout of the study	41
9	Materials used to make the Vermicompost Tea solution	45
10	Creating the mix for the Vermicompost Tea solution	45
11	The greenhouse used in the study	47
12	Temperature record data for 30 days	48
13	Relative humidity record data for 30 days	49
14	Water level data for the mister system in 30 days	50
15	Established fogponics system for Chinese kale production	51
16	Monitoring of the TDS and pH levels of the nutrient solution	54
17	Daily record of the pH values in the four treatments	55
18	Daily record of the TDS values in the four treatments	55
		PAGE
19	Recorded nutrient solution temperature for the fogponics system per hour	56

20	Daily record of the Electrical Conductivity values in the four treatments	58
21	Nutrient solution level comparison between fogponics and hydroponics systems	60
22	Plant height measurement of Chinese kale throughout the observation period	63
23	Leaf length measurement of Chinese kale throughout the observation period	65
24	Leaf width measurement of Chinese kale throughout the observation period	67
25	Number of leaves of Chinese kale throughout the observation period	69
26	Root length of Chinese kale throughout the observation period	71
27	Yield weight of Chinese kale throughout the observation period	73

LIST OF APPENDIX TABLES

APPENDIX TABLE		PAGE
1	Specification of the frame of the fogponics system	100
2	Specification of the Gallon Reservoir of the fogponics system	100
3	Specification of the Gallon Reservoir Lid of the fogponics system	100
4	Estimated Billing of Materials	100
5	Operating cost	102
6	Maintenance and replacement cost	102
7	Miscellaneous cost	102
8	Analysis of Variance table with the response variable: mean plant height	102
9	Pairwise mean comparison of treatment: Least Significant Difference (LSD) Test for the plant height	102
10	Analysis of Variance table with the response variable: average leaf length	103
11	Pairwise mean comparison of treatment: Least Significant Difference (LSD) Test for the leaf length	103
12	Analysis of Variance table with the response variable: average leaf width	103
13	Pairwise mean comparison of treatment: Least Significant Difference (LSD) Test for the leaf width	103
14	Analysis of Variance table with the response variable: leaf count	104
15	Pairwise mean comparison of treatment: Least Significant Difference (LSD) Test for the number of leaves	104
16	Analysis of Variance table with the response variable: root length	104

17	Pairwise mean comparison of treatment: Least Significant Difference (LSD) Test for the root length	104
18	Analysis of Variance table with the response variable: yield weight	105
19	Pairwise mean comparison of treatment: Least Significant Difference (LSD) Test for the yield weight	105

LIST OF APPENDIX FIGURES

FIGURE		PAGE
1	Floorplan of the greenhouse	106
2	Front and Rear elevation of the greenhouse	107
3	Side elevation of the greenhouse	108
4	Perspective view of the greenhouse	109
5	Perspective view of the fogponics system	110
6	Cross-section view of the fogponics system	111
7	Testing of the system prior to actual usage	112
8	Testing of the sprinkler	112
9	Finished setup of the IoT system	113
10	Chinese kale seedling preparation	113
11	Transplanting of the seedlings	114
12	Monitoring of different parameters using data logger	114
13	User interface of the Blynk platform	115
14	Preparation of the vermicompost tea solution	116
15	Nutrient solution temperature checking	116
16	Result of vermicompost tea analysis	117
17	Chinese kale at the start of the observation	118
18	Chinese kale during the final day of observation	118
19	Data gathering of different growth parameters	119
20a	Weighing of the samples: Treatment 1	119

	PAGE
20b Weighing of the samples: Treatment 2	120
20c Weighing of the samples: Treatment 3	120
20d Weighing of the samples: Treatment 4	121

ABSTRACT

EVANGELISTA, KENNETH T. Department of Agricultural and Biosystems Engineering, College of Engineering, Central Luzon State University, Science City of Muñoz, Nueva Ecija, **JULY 2024. EVALUATION OF VERMICOMPOST TEA IN FOGPONICS SYSTEM WITH INTEGRATION OF INTERNET OF THINGS FOR CHINESE KALE (*Brassica oleracea*) PRODUCTION**

Adviser: JOHN PAULO C. SACDALAN, Ph. D.

Fogponics is a modernized version of the Aeroponics farming system, often known as "Aeroponics 2.0." Fogponics systems with IoT offers improved automation and control. Also, it offers significant potential for enhancing Chinese kale's (*Brassica oleracea*) production. By varying the nutrient solution's concentrations within predefined ranges, the study explores their effects on the overall crop performance of the system. The fog is produced by placing an ultrasonic fog generator inside the mixture of nutrient solution and plant nutrients inside an enclosed reservoir. Furthermore, the fogging frequency was set to be operational for 30 minutes followed by a 15-minute off. For treatment 1, the concentration used was 10% vermicompost tea to 90% commercial solution in fogponics system. In treatment 2, the concentration used was 25% vermicompost tea to 75% commercial solution in fogponics system. For Treatment 3, equal amounts of vermicompost tea and commercial solution were used in fogponics system. Lastly, for Treatment 4 which served as the control treatment, 100% commercial solution in hydroponics system was used. For the treatments involving the fogponics system, the 30 minutes on – 15 minutes off fogging frequency was used, while for the hydroponics system, the bottom part of the net cups were submerged to the nutrient solution at a depth of 1 inch

for good nutrient uptake from the roots. The programming language used in the automation was C++. The findings show that Chinese kale on Treatment 1 produced the most optimal performance among all the treatments, however, most of the results incurred that there is no significant difference between using Treatment 1 and Treatment 4. Comparison between the fogponics system and the hydroponics system shows that there is a relatively high difference in their water consumption. The results showed that the fogponics system used 61% less water than the hydroponics system which signifies that fogponics system efficiently manages the application of water to the crops' roots better than the hydroponics system. The IoT-enabled fogponics system demonstrated its ability to minimize human effort, provide remote monitoring and control capabilities that allow precise adjustment of environmental conditions, leading to optimal plant development. This research contributes to the field of sustainable agriculture by combining fogponics and IoT technologies to enhance crop cultivation, offering potential benefits such as increased productivity, and resource conservation.

Keywords: Fogponics System, Automation, Irrigation, Internet of Things, Chinese Kale

LITERATURE CITED

- AgriFarming. (2015). *Kale Cultivation; Farming Practices; Care; Harvesting*.
https://www.agrifarming.in/Kale-Cultivation#google_vignette.
- Agrotomy. (2023). *Aeroponics versus Conventional Hydroponics*.
<https://agrotomy.com/aeroponics-versus-conventional-hydroponics/#:~:Text=In%20a%20hydroponic%20system%2C%20plants,50%25%20less%20water%20than%20hydroponics>.
- AirGarden. (2023). *Aeroponics vs Hydroponics - Learning the Difference*.
<https://airgarden.com.au/blogs/news/aeroponics-vs-hydroponics/#:~:text=Water%20Usage&text=However%20when%20it%20comes%20to,aeroponics%20saves%20you%2095%25!>
- Akkaş, M. A., & Sokullu, R. (2017). An IoT-based greenhouse monitoring system with Micaz motes. *Procedia Computer Science*, 113, 603–608.
<https://doi.org/10.1016/J.PROCS.2017.08.300>
- Alexopoulos, A. A., Marandos, E., Assimakopoulou, A., Vidalis, N., Petropoulos, S. A., & Karapanos, I. C. (2021). Effect of Nutrient Solution pH on the Growth, Yield and Quality of *Taraxacum officinale* and *Reichardia picroides* in a Floating Hydroponic System. *Agronomy*, 11(6).
<https://doi.org/10.3390/agronomy11061118>
- Ali, S., Rahman, J., Islam, M., Ali, R., Hossain, M., Ali, M., Ahmed, S., & Chandni, C. (2021). EFFECT OF NUTRIENT SOLUTION ON GROWTH AND YIELD OF CHERRY TOMATO VARIETIES IN SOILLESS CULTURE. *International Journal of Research -GRANTHAALAYAH*, 9, 235–251.
<https://doi.org/10.29121/granthaalayah.v9.i10.2021.4244>
- Alkobaisy, J. S., Abdel Ghani, E. T., Mutlag, N. A., & Lafi, A. S. A. (2021). Effect of Vermicompost and Vermicompost tea on the Growth and Yield of Broccoli and Some Soil Properties. *IOP Conference Series: Earth and Environmental Science*, 761(1). <https://doi.org/10.1088/1755-1315/761/1/012008>
- Al-Kodmany, K. (2011). Tall Buildings, Design, and Technology: Visions for the Twenty-First Century City. *Journal of Urban Technology*, 18(3), 115–140.
<https://doi.org/10.1080/10630732.2011.615573>
- Al-Kodmany, K. (2018). The vertical farm: A review of developments and implications for the vertical city. In *Buildings* (Vol. 8, Issue 2). MDPI AG.
<https://doi.org/10.3390/buildings8020024>

- Arancon, N. Q., Edwards, C. A., Babenko, A., Cannon, J., Galvis, P., & Metzger, J. D. (2008a). Influences of vermicomposts, produced by earthworms and microorganisms from cattle manure, food waste and paper waste, on the germination, growth and flowering of petunias in the greenhouse. *Applied Soil Ecology*, 39(1), 91–99. <https://doi.org/10.1016/J.APSOIL.2007.11.010>
- Arancon, N. Q., Edwards, C. A., Babenko, A., Cannon, J., Galvis, P., & Metzger, J. D. (2008b). Influences of vermicomposts, produced by earthworms and microorganisms from cattle manure, food waste and paper waste, on the germination, growth and flowering of petunias in the greenhouse. *Applied Soil Ecology*, 39(1), 91–99. <https://doi.org/10.1016/J.APSOIL.2007.11.010>
- Arancon, N. Q., Edwards, C. A., Lee, S., & Byrne, R. (2006). Effects of humic acids from vermicomposts on plant growth. *European Journal of Soil Biology*, 42(SUPPL. 1), S65–S69. <https://doi.org/10.1016/J.EJSOBI.2006.06.004>
- Arancon, N. Q., Owens, J. D., & Converse, C. (2019). The effects of vermicompost tea on the growth and yield of lettuce and tomato in a non-circulating hydroponics system. *Journal of Plant Nutrition*, 42(19), 2447–2458. <https://doi.org/10.1080/01904167.2019.1655049>
- Arya, L. M., Pulver, E. L., & van Genuchten, M. T. (2001). Economic, Environmental, and Natural Resource Benefits of Plastic Shelters in Vegetable Production in a Humid Tropical Environment. *Journal of Sustainable Agriculture*, 17(2–3), 123–143. https://doi.org/10.1300/J064v17n02_12
- Aslam, Z. (2020). Effects of vermicompost, vermi-tea and chemical fertilizer on morpho-physiological characteristics of tomato (*Solanum lycopersicum*) in Suleymanpasa District, Tekirdag of Turkey. *Pure and Applied Biology*, 9(3). <https://doi.org/10.19045/bspab.2020.90205>
- Aslam, Z., & Ahmad, A. (2020). Effects of Vermicompost, Vermi-tea and Chemical Fertilizer on Morpho-physiological Characteristics of Maize (*Zea mays* L.) in Suleymanpasa District, Tekirdag of Turkey. *Journal of Innovative Sciences*, 6(1). <https://doi.org/10.17582/journal.jis/2020/6.1.41.46>
- Azarmi, R., Torabi Giglou, M., & Hajieghrari, B. (2009). The effect of sheep-manure vermicompost on quantitative and qualitative properties of cucumber (*Cucumis sativus* L.) grown in the greenhouse. *AFRICAN JOURNAL OF BIOTECHNOLOGY*, 8. <https://doi.org/10.4314/ajb.v8i19.65198>
- Aznar-Sánchez, J. A., Velasco-Muñoz, J. F., López-Felices, B., & Román-Sánchez, I. M. (2020). An analysis of global research trends on greenhouse technology:

- Towards a sustainable agriculture. *International Journal of Environmental Research and Public Health*, 17(2). <https://doi.org/10.3390/ijerph17020664>
- Barani, P., & Anburani, A. (2004). Influence of vermicomposting on major nutrients in bhendi (*Abelmoschus esculentus* L. Moench) cv. Arka Anamika. *South Indian Horticulture*, 52(1/6), 170–174. <https://eurekamag.com/research/004/205/004205793.php>
- Bhandari, P., Kimothi, M., Tech Scholar, M., & Prof, A. (2018). IJESRT INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY IOT BASED DESIGN IMPLEMENTATION OF MUSHROOM FARM MONITORING USING ARDUINO MICROCONTROLLERS & SENSORS. *International Journal of Engineering Sciences & Research Technology*, 550. <https://doi.org/10.5281/zenodo.1252927>
- Bhattacharjee, M. (2015). What is correlation between temperature and pH? Does high temperature tend to decrease the pH? In <https://www.researchgate.net/post/What-is-correlation-between-temperature-and-pH-Does-high-temperature-tend-to-decrease-the-pH/54eb20a0d3df3e10228b45c6/citation/download>.
- Bouchard, K. (2017). *Fogponics: A New Spin on Aeroponic Gardens*. <https://www.maximumyield.com/fogponics-a-new-spin-on-aeroponic-gardens/2/1401>
- Canellas, L. P., Olivares, F. L., Okorokova-Façanha, A. L., & Façanha, A. R. (2002). Humic acids isolated from earthworm compost enhance root elongation, lateral root emergence, and plasma membrane H⁺-ATPase activity in maize roots. *Plant Physiology*, 130(4), 1951–1957. <https://doi.org/10.1104/pp.007088>
- Chander, S. (2023). Influence of Total Dissolved Solids (TDS) on Hydroponic Spinach Growth and Yield: A Six-Week Study. *International Research Journal of Modernization in Engineering Technology and Science*. <https://doi.org/10.56726/irjmets43551>
- Chebudie, A. B., Minerva, R., & Rotondi, D. (2014). *Towards a definition of the Internet of Things (IoT)*. https://www.researchgate.net/publication/317588072_Towards_a_definition_of_the_Internet_of_Things_IoT
- Chel, A., & Kaushik, G. (2011). Renewable energy for sustainable agriculture. *Agronomy for Sustainable Development*, 31(1), 91–118. <https://doi.org/10.1051/agro/2010029>

- Dagar, R., Som, S., & Khatri, S. K. (2018). *Smart Farming – IoT in Agriculture*.
<https://doi.org/10.1109/ICIRCA.2018.8597264>
- Dan, L., Xin, C., Chongwei, H., & Liangliang, J. (2015). *Intelligent Agriculture Greenhouse Environment Monitoring System Based on IOT Technology*.
<https://doi.org/10.1109/ICITBS.2015.126>
- Dewangan, S. K., Shrivastava, S., Kadri, M., Saruta, S., Yadav, S., & Minj, N. (2023). “TEMPERATURE EFFECT ON ELECTRICAL CONDUCTIVITY(EC) & TOTAL DISSOLVED SOLIDS (TDS) OF WATER: A REVIEW.”
https://www.researchgate.net/publication/371539432_TEMPERATURE_EFFECT_ON_ELECTRICAL_CONDUCTIVITYEC_TOTAL_DISSOLVED_SOLID_S_TDS_OF_WATER_A_REVIEW/Citation/Download,10,514-520
- Ding, X., Jiang, Y., Zhao, H., Guo, D., He, L., Liu, F., Zhou, Q., Nandwani, D., Hui, D., & Yu, J. (2018). Electrical conductivity of nutrient solution influenced photosynthesis, quality, and antioxidant enzyme activity of pakchoi (*Brassica campestris* L. Ssp. *Chinensis*) in a hydroponic system. *PLoS ONE*, *13*(8).
<https://doi.org/10.1371/journal.pone.0202090>
- Ebenezer D, V. R., C, V. A., & Lekha, S. S. (2020). A STUDY ON DEVELOPMENT OF CROPS BY FOGPONIC SYSTEM USING COCO COIR. *International Research Journal of Engineering and Technology*.
www.irjet.net
- E-buyer’s Guide Phillippines. (2014). Where to buy Kale in Manila.
<https://ebuyersguideph.blogspot.com/2014/09/Where-to-Buy-Kale-in-Manila.html>
- Edwards, C., Arancon, N., Emerson, E., & Pulliam, R. (2007). *Suppressing Plant Parasitic Nematodes And Arthropod Pests With Vermicompost Teas*.
<https://www.biocycle.net/suppressing-plant-parasitic-nematodes-and-arthropod-pests-with-vermicompost-teas/>
- Edwards, C., Arancon, N., & Greytak, S. (2016). *EFFECTS OF VERMICOMPOST TEAS ON PLANT GROWTH AND DISEASE*.
- Eldridge, B. M., Manzoni, L. R., Graham, C. A., Rodgers, B., Farmer, J. R., & Dodd, A. N. (2020). Getting to the roots of aeroponic indoor farming. *New Phytologist*, *228*(4), 1183–1192. <https://doi.org/10.1111/nph.16780>

- Esteban, J., Belen, I., & Miculob, M. (2017). Vermicompost Tea: Effects on Germination of Saluyot (*Corchorus olitorius*). *International Journal of Education and Research*, Vol. 5(No. 9).
- Fernandez, J., Orsini, F., Baeza, E., Oztekin, G., Muñoz, P., Contreras, J., & Montero, J. I. (2018). Current trends in protected cultivation in Mediterranean climates. *European Journal of Horticultural Science*, 83, 294–305. <https://doi.org/10.17660/eJHS.2018/83.5.3>
- Fontanilla. (2014, September 27). *Where To Buy Kale in Manila*. [Http://Ebuyersguideph.Blogspot.Com/2014/09/Where-to-Buy-Kale-in-Manila.Html](http://Ebuyersguideph.Blogspot.Com/2014/09/Where-to-Buy-Kale-in-Manila.Html).
- Food and Agriculture Organizations of the United Nations. (2022). The dimensions of water productivity. <https://www.Fao.Org/3/Cc2724en/Cc2724en.Pdf>.
- Fritz, J. I., Franke-Whittle, I. H., Haindl, S., Insam, H., & Braun, R. (2012). Microbiological community analysis of vermicompost tea and its influence on the growth of vegetables and cereals. <https://doi.org/10.1139/W2012-061>, 58(7), 836–847. <https://doi.org/10.1139/W2012-061>
- Gomes, T., Brito, J., Abreu, H., Gomes, H., & Cabral, J. (2015). GreenMon: An efficient wireless sensor network monitoring solution for greenhouses. In *Proceedings of the IEEE International Conference on Industrial Technology* (Vol. 2015). <https://doi.org/10.1109/ICIT.2015.7125420>
- Green. (2021). *All You Need to Know Growing Kale in a Vertical Hydroponic Greenhouse*. <https://www.Edengreen.Com/Blog-Collection/Hydroponic-Kale#:~:Text=After%20germination%2C%20you'll%20want,A%20pH%20of%20around%206.0>.
- Guo, T., & Zhong, W. (2015). *Design and implementation of the span greenhouse agriculture Internet of Things system*. <https://doi.org/10.1109/FPM.2015.7337148>
- Gutiérrez-Miceli, F. A., Santiago-Borraz, J., Montes Molina, J. A., Nafate, C. C., Abud-Archila, M., Oliva Llaven, M. A., Rincón-Rosales, R., & Dendooven, L. (2007). Vermicompost as a soil supplement to improve growth, yield and fruit quality of tomato (*Lycopersicum esculentum*). *Bioresource Technology*, 98(15), 2781–2786. <https://doi.org/10.1016/J.BIORTECH.2006.02.032>
- Hassan, J. A., & Jasim, B. H. (2021). Design and implementation of internet of things-based electrical monitoring system. *Bulletin of Electrical Engineering and Informatics*, 10(6), 3052–3063. <https://doi.org/10.11591/eei.v10i6.3155>

- Herbivore Phiippines. (2019). Kailaan.
<https://Herbivore.Com.Ph/Products/Kailan#:~:Text=Commonly%20known%20as%20Chinese%20broccoli,For%20%E2%82%B1250%20per%20250g>.
- Ievinsh, G. (2011). Vermicompost treatment differentially affects seed germination, seedling growth and physiological status of vegetable crop species. *Plant Growth Regulation*, 65(1), 169–181. <https://doi.org/10.1007/s10725-011-9586-x>
- Ingham, E. R. (2003). *compost tea brewing manual*. <https://doi.org/10.3/JQUERY-UI.JS>
- Jones, F. C. (2018). *The Influence of Color on Heat Absorption Item Type Report; text*.
<http://creativecommons.org/publicdomain/mark/1.0/LinktoItemhttp://hdl.handle.net/10150/637634>
- Keeling, A. A., McCallum, K. R., & Beckwith, C. P. (2003). Mature green waste compost enhances growth and nitrogen uptake in wheat (*Triticum aestivum* L.) and oilseed rape (*Brassica napus* L.) through the action of water-extractable factors. *Bioresource Technology*, 90(2), 127–132.
[https://doi.org/10.1016/S0960-8524\(03\)00125-1](https://doi.org/10.1016/S0960-8524(03)00125-1)
- Kiplagat, Mumu, Ndegwa, & Luta. (2019). Kale Production.
https://www.jica.go.jp/Project/English/Kenya/015/Materials/C8h0vm0000f7o8cj-Att/Materials_24.Pdf
https://www.jica.go.jp/project/english/kenya/015/materials/c8h0vm0000f7o8cj-att/materials_24.pdf
- Koohakan, P., Jeanaksorn, T., & Nuntagij, I. (2007). MAJOR DISEASES OF LETTUCE GROWN BY COMMERCIAL NUTRIENT FILM TECHNIQUE IN THAILAND. In *KMITL Sci. Tech. J* (Vol. 8, Issue 2).
- Kumar, R., Rathore, S., Kundlas, K., Rattan, S., & Warghat, A. R. (2023). Chapter 8 - Vertical farming and organic farming integration: a review. In Sarathchandran, U. M.R., S. Thomas, & D. K. Meena (Eds.), *Organic Farming (Second Edition)* (pp. 291–315). Woodhead Publishing.
<https://doi.org/https://doi.org/10.1016/B978-0-323-99145-2.00002-1>
- Lee, J., Lee, H., Lee, S., Kwak, K., Kim, B., Kim, T., Baek, J., Rho, S., & Hong, Y. (2019). Effects of Environmental Substrate Composition on the Growth and Yield of Hydroponically Grown Tomato. *Journal of Environmental Science International*, 28, 729–735. <https://doi.org/10.5322/JESI.2019.28.9.729>

- Li, Q., Li, X., Tang, B., & Gu, M. (2018). Growth Response and Root Characteristics of Lettuce Grown in Aeroponics, Hydroponics and Substrate Culture. https://www.researchgate.net/publication/327555237_Growth_Response_and_Root_Characteristics_of_Lettuce_Grown_in_Aeroponics_Hydroponics_and_Substrate_Culture/Citation/Download.
<https://doi.org/10.20944/preprints201809.0108.v1>
- Magwaza, S. T., Magwaza, L. S., Odindo, A. O., & Mditshwa, A. (2020). Hydroponic technology as decentralised system for domestic wastewater treatment and vegetable production in urban agriculture: A review. *Science of The Total Environment*, 698, 134154.
<https://doi.org/https://doi.org/10.1016/j.scitotenv.2019.134154>
- Medina, M., Jayachandran, K., Bhat, M. G., & Deoraj, A. (2016). Assessing plant growth, water quality and economic effects from application of a plant-based aquafeed in a recirculating aquaponic system. *Aquaculture International*, 24(1), 415–427. <https://doi.org/10.1007/s10499-015-9934-3>
- Meghvansi, M. K., Khan, M. H., Gupta, R., Gogoi, H. K., & Singh, L. (2012). Vegetative and Yield Attributes of Okra and Naga Chilli as Affected by Foliar Sprays of Vermiwash on Acidic Soil. *Journal of Crop Improvement*, 26(4), 520–531. <https://doi.org/10.1080/15427528.2012.657293>
- Mekonnen, Y., Namuduri, S., Burton, L., Sarwat, A., & Bhansali, S. (2020). Review—Machine Learning Techniques in Wireless Sensor Network Based Precision Agriculture. *Journal of The Electrochemical Society*, 167, 037522. <https://doi.org/10.1149/2.0222003JES>
- Miyasaki, & Ramirez. (2023). *Hydroponics System for Kale (Brassica Oleracea) production using vermicompost tea as nutrient solution.*
- Modu, F., Adam, A., Aliyu, F., Mabu, A., & Musa, M. (2020). A survey of smart hydroponic systems. *Advances in Science, Technology and Engineering Systems*, 5(1), 233–248. <https://doi.org/10.25046/aj050130>
- Mohd Yattoo, A., Niamat Ali, M., Ahmad Baba, Z., & Hassan, B. (2021). *Sustainable management of diseases and pests in crops by vermicompost and vermicompost tea. A review.* <https://doi.org/10.1007/s13593-020-00657-w>/Published
- Montefrio, M. J. F. (2020a). The ‘queen of greens’ comes to the tropics: (De)Territorialization of kale’s socio-material relations in the Philippines. *Geoforum*, 116, 24–32. <https://doi.org/10.1016/j.geoforum.2020.07.015>

- Montefrio, M. J. F. (2020b). The 'queen of greens' comes to the tropics: (De)Territorialization of kale's socio-material relations in the Philippines. *Geoforum*, *116*, 24–32. <https://doi.org/10.1016/j.geoforum.2020.07.015>
- Naidu, Y., Meon, S., Kadir, J., Siddiqui, Y., & Malaysia, S. (2010). Microbial Starter for the Enhancement of Biological Activity of Compost Tea. *ISSN OnlineHNB*, *12*, 1560–8530.
- Nitsan. (2023). Water Replacement in DWC: The When, Why, and How. <https://Getgrowee.Com/Dwc-Water-Change/>.
- Pant, A., Radovich, T., Hue, N., Talcott, S., & Krenek, K. (2009). *Vermicompost extracts influence growth, mineral nutrients, phytonutrients and antioxidant activity in pak choi (Brassica rapa cv. Bonsai, Chinensis group) grown under vermicompost and chemical fertiliser.*
- Patterson. (2012). *Growing Chinese Broccoli Plants: Learn About The Care Of Chinese Broccoli.*
<https://www.gardeningknowhow.com/edible/vegetables/chinese-kale/growing-chinese-broccoli.htm>.
- Postma, J., van Os, E., & Bonants, P. J. M. (2008). PATHOGEN DETECTION AND MANAGEMENT STRATEGIES IN SOILLESS PLANT GROWING SYSTEMS. *Soilless Culture: Theory and Practice*, 425–457.
<https://doi.org/10.1016/B978-044452975-6.50012-5>
- Pradhan, B., & Deo, B. (2019). Soilless farming – the next generation green revolution. *Current Science*, *116*(5), 728–732.
<https://www.jstor.org/stable/27137929>
- Rakib Uddin, M., & Suliaman, M. F. (2021). Energy efficient smart indoor fogponics farming system. *IOP Conference Series: Earth and Environmental Science*, *673*(1). <https://doi.org/10.1088/1755-1315/673/1/012012>
- Rana, M. K., & Karthik, R. (2017). Chinese Broccoli / Chinese Kale. <https://www.taylorfrancis.com/chapters/edit/10.1201/9781315116204-33/Chinese-Broccoli-Chinese-Kale-Rana-Karthik-Reddy>, 1–10.
- Ratnaparkhi, S., Khan, S., Arya, C., Khapre, S., Singh, P., Diwakar, M., & Shankar, A. (2020). Smart agriculture sensors in IOT: A review. *Materials Today: Proceedings*. <https://doi.org/10.1016/j.matpr.2020.11.138>
- Rayhana, R., Xiao, G., & Liu, Z. (2020). Internet of Things Empowered Smart Greenhouse Farming. *IEEE Journal of Radio Frequency Identification*, *4*(3), 195–211. <https://doi.org/10.1109/JRFID.2020.2984391>

- Reja, M., Ghosh, A., Nalia, A., & Nath, R. (2019). Vertical Farming: A New Prospect of Landless Farming. https://www.researchgate.net/publication/340720785_Vertical_Farming_A_New_Prospect_of_Landless_Farming, 6, 108–112.
- Research Online, G. (2009). Earthworms Vermicompost: A Powerful Crop Nutrient over the Conventional Compost & Protective Soil Conditioner against the Destructive Chemical Fertilizers for Food Safety and Security Author Link to published version Earthworms Vermicompost: A Powerful Crop Nutrient over the Conventional Compost & Protective Soil Conditioner against the Destructive Chemical Fertilizers for Food Safety and Security. In *J. Agric. & Environ. Sci* (Vol. 5, Issue S). <http://hdl.handle.net/10072/30336http://www.idosi.org/aejaes/aejaes5>
- Sengupta, A., & Banerjee, H. (2012). Soil-less culture in modern agriculture. In *World Journal of Science and Technology* (Vol. 2012, Issue 7). www.worldjournalofscience.com
- Shamshiri, R., Jones, J., Thorp, K., Ahmad, D., Che Man, H., & Taheri, S. (2018). Review of optimum temperature, humidity, and vapour pressure deficit for microclimate evaluation and control in greenhouse cultivation of tomato: A review. *International Agrophysics*, 32, 287–302. <https://doi.org/10.1515/intag-2017-0005>
- Sharma, A., Jain, A., Gupta, P., & Chowdary, V. (2020). Machine Learning Applications for Precision Agriculture: A Comprehensive Review. *IEEE Access*, PP, 1. <https://doi.org/10.1109/ACCESS.2020.3048415>
- Singh, R., Sharma, R. R., Kumar, S., Gupta, R. K., & Patil, R. T. (2008). Vermicompost substitution influences growth, physiological disorders, fruit yield and quality of strawberry (*Fragaria x ananassa* Duch.). *Bioresource Technology*, 99(17), 8507–8511. <https://doi.org/10.1016/J.BIORTECH.2008.03.034>
- Singh, S., Singh, D. R., Velmurugan, A., Jaisankar, I., & Swarnam, T. P. (2018). Coping with climatic uncertainties through improved production technologies in tropical island conditions. In *Biodiversity and Climate Change Adaptation in Tropical Islands* (pp. 623–666). Elsevier. <https://doi.org/10.1016/B978-0-12-813064-3.00023-5>
- Sinha, R. (2010). The wonders of earthworms & its vermicompost in farm production: Charles Darwin's 'friends of farmers', with potential to replace

- destructive chemical fertilizers. *Agricultural Sciences*, 01, 76–94.
<https://doi.org/10.4236/as.2010.12011>
- Snigdha, S., & Madhu, B. (2017). SMART AGRICULTURE: A BLISS TO FARMERS. *International Journal of Engineering Sciences & Research Technology*. <https://doi.org/10.5281/zenodo.546306>
- Soffer, H., & Burger, D. (1988). Effects of Dissolved Oxygen Concentrations in Aero-hydroponics on the Formation and Growth of Adventitious Roots. *Journal of the American Society for Horticultural Science*, 113.
<https://doi.org/10.21273/JASHS.113.2.218>
- Sreekumar, V. (2020). DROPLET SIZE ANALYSIS OF HIGH PRESSURE AEROPONIC SYSTEM.
https://www.academia.edu/45660017/DROPLET_SIZE_ANALYSIS_OF_HIGH_PRESSURE_AEROPONIC_SYSTEM
https://www.academia.edu/45660017/DROPLET_SIZE_ANALYSIS_OF_HIGH_PRESSURE_AEROPONIC_SYSTEM
- Stein, E. W. (2021). The Transformative Environmental Effects Large-Scale Indoor Farming May Have On Air, Water, and Soil. *Air, Soil and Water Research*, 14, 1178622121995819. <https://doi.org/10.1177/1178622121995819>
- Sutton, J. C. (2007). DISEASE MANAGEMENT IN CROPS PRODUCED IN RECIRCULATING HYDROPONIC SYSTEMS.
<https://Ag.Umass.Edu/Sites/Agcenter/Files/Pdf-Doc-Ppt/2007DiseaseMgt.Pdf>.
- Suwastika, N. A., Helmi, M., Aulia, M. M. S., & Wardana, A. A. (2022). Design of a Fogponics Farming System based on the Internet of Things and Fuzzy Logic. *2022 2nd International Conference on Intelligent Cybernetics Technology & Applications (ICICyTA)*, 99–104.
<https://doi.org/10.1109/ICICyTA57421.2022.10038174>
- Tibbitts, T. W., Cao, W., & Wheeler, R. M. (1994). Growth of Potatoes for CELSS.
https://www.researchgate.net/publication/24293311_Growth_of_potatoes_for_CELSS.
- Tridge. (2023). Kale Market Overview.
<https://www.tridge.com/intelligences/kale>.
- Truong, H. D., Wang, C. H., & Trung Kien, T. (2017). Effects of Continuously Applied Vermicompost on Media Properties, Growth, Yield, and Fruit Quality of Two Tomato Varieties. *Communications in Soil Science and Plant Analysis*, 48(4), 370–382. <https://doi.org/10.1080/00103624.2016.1261887>

- Van, M. (2000). *EC and pH: What Is It and Why Does It Matter?*
<http://www.ces.ncsu.edu/depts/hort/floriculture/>
- Varshney, A., Sharma, U., & Singh, B. (2020). *A Grid Interactive Sensorless Synchronous Reluctance Motor Drive for Solar Powered Water Pump for Agriculture and Residential Applications.*
<https://doi.org/10.1109/PEDES49360.2020.9379885>
- Von Bieberstein, P., Xu, Y., Gunatilaka, L., & Gruener, R. (2014). Biomass Production and Withaferin A Synthesis by *Withania somnifera* Grown in Aeroponics and Hydroponics. *HortScience: A Publication of the American Society for Horticultural Science*, 49, 1506–1509.
<https://doi.org/10.21273/HORTSCI.49.12.1506>
- Watson, M. (2006). Fogponic Plant Growth System.
<https://Patents.Google.Com/Patent/CA2892131A1/En>.
- West Fraser. (2017). THE PHYSICS OF FOIL HEAT GAIN / LOSS IN BUILDINGS. <https://Osب.Westfraser.Com/Wp-Content/Uploads/2017/05/The-Physics-of-Foil.Pdf>.
- Williams-Woodward, J. (2022). Root disease management in hydroponic systems.
<https://www.e-gro.org/Pdf/E706.Pdf>. <http://e-gro.org/pdf/E703.pdf>
- Wootton-Beard, & Peter. (2019). *Producing fodder crops using hydroponics.*
https://pure.aber.ac.uk/portal/files/29731969/technical_article_hydroponic_fodder.pdf
- Yatoo, A. M., Ali, M. N., Baba, Z. A., & Hassan, B. (2021). Sustainable management of diseases and pests in crops by vermicompost and vermicompost tea. A review. *Agronomy for Sustainable Development* 2021 41:1, 41(1), 1–26.
<https://doi.org/10.1007/S13593-020-00657-W>
- Yield, M. (2018). *What is Fogponics? - Definition from Maximum Yield.*
<https://www.maximumyield.com/definition/160/fogponics>
- Zamora-Izquierdo, M. A., Santa, J., Martínez, J. A., Martínez, V., & Skarmeta, A. F. (2019). Smart farming IoT platform based on edge and cloud computing. *Biosystems Engineering*, 177, 4–17.
<https://doi.org/10.1016/J.BIOSYSTEMSENG.2018.10.014>
- Zhang, H., Asutosh, A., & Hu, W. (2018). Implementing vertical farming at university scale to promote sustainable communities: A feasibility analysis. *Sustainability (Switzerland)*, 10(12). <https://doi.org/10.3390/su10124429>

Zheng, J., Sutton, J., & Yu, H. (2009). Interactions among *Pythium aphanidermatum*, roots, root mucilage, and microbial agents in hydroponic cucumbers. *Canadian Journal of Plant Pathology*, December 2000, 368–379. <https://doi.org/10.1080/07060660009500455>

ZipGrow. (2014). Water Use Efficiency in Hydroponics and Aquaponics. <https://zipgrow.com/water-use-efficiency-hydroponics-aquaponics/>.