

**VERTICAL GARDEN SYSTEM FOR TOMATO (*Lycopersicon esculentum* Mill.)
PRODUCTION USING DIFFERENT SOIL CONDITIONER UNDER
PROTECTED STRUCTURE**

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An Undergraduate Thesis Submitted to the Faculty of the Department of Agricultural
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**BACHELOR OF SCIENCE IN AGRICULTURAL AND BIOSYSTEMS
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ACCEPTANCE SHEET

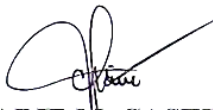
This undergraduate thesis entitled, “**VERTICAL GARDEN SYSTEM FOR TOMATO (*Lycopersicon esculentum* Mill.) PRODUCTION USING DIFFERENT SOIL CONDITIONER UNDER PROTECTED STRUCTURE,**” prepared and submitted by **BRAVELY JEHU F. FERNANDEZ**, in partial fulfillment of the requirements for the degree of **BACHELOR OF SCIENCE IN AGRICULTURAL AND BIOSYSTEMS ENGINEERING (LAND AND WATER RESOURCES ENGINEERING)** is hereby accepted:


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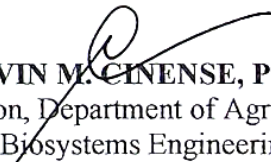

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ABSTRACT

FERNANDEZ, BRAVELY JEHU F., Department of Agricultural and Biosystems Engineering, College of Engineering, Central Luzon State University, Science City of Muñoz , Nueva Ecija, Philippines, **June 2019, VERTICAL GARDEN SYSTEM FOR TOMATO (*Lycopersicon esculentum* Mill.) PRODUCTION USING DIFFERENT SOIL CONDITIONER UNDER PROTECTED STRUCTURE**

Adviser: CLAIRE MARIE M. CASTILLO, M.Sc.

This study aimed to increase the yield of tomato through vertical garden system and improve the growth of tomato using different soil conditioner under protected structure. Specifically, the study aimed to maximize the available land space and use the water efficiently for irrigation using vertical farming with drip irrigation system under ridge type protected structure, determine the most effective soil conditioner such as coco dust, carabao manure and chicken manure for tomato production, and to perform the costing using this emerging type of production system.

This study used low cost materials and locally available materials in the nearby market. The vertical garden was constructed according to its plan and its measurement using bamboo and other available wood materials. Drip irrigation system was installed for the tomato production under ridge type protected structure using low cost materials and recycled materials that were readily available at the farm such as lateral lines, polyethylene pipes and water reservoir.

The study was laid out in Complete Randomized Design (CRD) and data gathered were analyzed using ANOVA and Least Significant Difference (LSD) for the comparison among treatment means. Different soil conditioner mixed with garden soil were used as treatments in this study.

Results showed that the tomato planted in the mixture of chicken manure and garden soil had obtained the tallest plant height followed by the tomato planted in the mixture of carabao manure and garden soil with a value of 59.94 cm and 59.428 cm, respectively. While the results revealed that highest average yield of plant was obtained from mixture of carabao manure and garden soil followed by the mixture of chicken manure and garden soil with a value of 78.18 g and 76.76 g, respectively.

Among the three soil conditioner used in the study, carabao manure was the most suitable media for the production of tomato. Furthermore, yield of Apollo tomato in the study can be increased using the vertical garden system for a reason that it had more number of plants per area with 6 plants/m² compared to traditional farming with only 2-4 plants/m² (depends on plant spacing).

Keywords: vertical garden system; ridge type protected structure; soil conditioner; drip irrigation

LITERATURE CITED

- Ambius. (2018). What are Vertical Gardens. Retrieved on November 8, 2018 at <https://www.ambius.com/green-walls/what-are-vertical-gardens/>
- Basic Knowledge 101. (2018). Vertical Farming – Indoor Agriculture. Retrieved on November 8, 2018 at www.basicknowledge101.com/subjects/verticalfarming.html
- Burpee. (2018). All About Tomatoes. How to Grow Tomatoes - Gardening Tips and Advice, Vegetable Seeds and Plants at Burpee.com. Retrieved on November 27, 2018 at <https://www.burpee.com/gardenadvicecenter/vegetables/tomatoes/all-about-tomatoes/article10033.html>
- Clarke, P. (2016). 20 Vertical Gardening Ideas for Turning a Small Space into a Big Harvest. Retrieved on October 2, 2018 at <http://waldenlabs.com/20-vertical-gardening-ideas/>
- Compost Direct. (2018). Soil Conditioner. Retrieved on September 29, 2018 at <https://www.compostdirect.com/soil-conditioner/p1>
- Cox, D., Clifton, N., Bartok, J., & Lascola, T. (2010). Massachusetts Greenhouse Industry Best Management Practices Guide. University of Massachusetts Extension. Retrieved on September 28, 2018
- Cuaresma, F., & Cabanayan, L. (2012). Compiled Lecture in Engineering Economy. Department of Engineering Sciences College of Engineering. Central Luzon State University. Science City of Munoz, Nueva Ecija
- De Guzman, R.M., Jr. (2004). Use of Different Planting Media for Tomato Production. Central Luzon State University.
- Del Rosario, Z. (2018). Construction of Vertical Garden for Hot Pepper (*Capsicum frutescens* L.) Production Using Different Compost Proportions under Protected Structure.
- Delp, R. The Best Animal Manure Fertilizers. Home Guides. Retrieved on December 10, 2018 at <http://homeguides.sfgate.com/animal-manure-fertilizers-73720.html>
- Delp, R. Tomato Fertilizer Requirements. Retrieved on November 27, 2018 at <https://homeguides.sfgate.com/tomato-fertilizer-requirements-41237.html>
- Department of Agriculture, Republic of the Philippines
- Department of Agriculture and Fisheries, State of Queensland. Land Requirements for Tomatoes. Retrieved on November 27, 2018 at <https://www.daf.qld.gov.au/business-priorities/plants/fruit-and-vegetables/vegetables/tomatoes/land-requirements-for-tomatoes>

- Duncan, J. (2005). Composting Chicken Manure. Retrieved on September 29, 2018 at www.seattletilth.org/learn/resources-1/city-chickens/compostingchickenmanure
- Food and Agriculture Organization of United Nation. (2011). The State of Food Insecurity in the World. Food and Agriculture Organization of the United Nation. Rome.
- Food and Fertilizer Technology Center. (2007). Protective Structures for Improved Crop Production.
- Gonzaga, Z., Capuno, O.B., Loreto, M.B., Gerona, R.G., Borines, L.M., Tulin, A.T., Mangmang, J.S., Lusanta, D.C., Dimabuyu, H.B. & Rogers, G.S. (2011). Low-Cost Protected Cultivation: Enhancing Year-Round Production of High Value Vegetables in the Philippines. Retrieved on September 28, 2018
- Hansen, V.E., Israelsen, O.W. & Stringam, G.E. (1980). Irrigation Principles and Practices. Fourth Edition. New York: John Wiley and Sons, Inc.
- Joshi, R. & Vig A.P. (2010). Effect of Vermicompost on Growth, Yield and Quality of Tomato (*Lycopersicum esculentum* L). Department of Botanical and Environmental Sciences, Guru Nanak Dev University, Amritsar-143005, Punjab, India.
- Kumar, A., & Tyagi, S. (2017). Protected Cultivation of Vegetable Crops. Bihar Agriculture University. Retrieved on September 29, 2018 at <https://www.researchgate.net/publication/321300522>
- Mears, D. R. (2004). Environmental Control in Protected Structure. Rutgers, The State University of New Jersey. Retrieved on September 26, 2018 at <https://www.researchgate.net/publication/279980531>
- Munroe, S. How Often Should You Fertilize Tomato Plants?. Retrieved on November 27, 2018 at <https://homeguides.sfgate.com/should-fertilize-tomato-plants-54719.html>
- National Greenhouse Manufacturer's Association. (2002). Greenhouse Curtain Systems. Retrieved on September 29, 2018 at gpnmag.com/article/greenhouse-curtain-systems/
- Nueva Ecija Fruits and Vegetables Seed Center. (2011). Maikling Gabay sa Produksyon ng Kamatis. Science City of Munoz, Nueva Ecija.
- Orzolek, M., Bogash, S., Harsh, R., Kime, L., & Harper, J. (2006). Tomato Production. College of Agricultural Sciences. The Pennsylvania State University 323

- Agricultural Administration Building University Park, PA 16802. Retrieved on November 27, 2018 at <https://extension.psu.edu/tomato-production>
- Philippine Statistics Authority. (2015). Special Report - Highlights of the 2012 Census of Agriculture (2012 CA). Retrieved on December 19, 2018 at <https://psa.gov.ph/content/special-report-highlights-2012-census-agriculture-2012-ca>
- Planters Group. (2018). Why Vertical Gardening Important?. Retrieved on November 8, 2018 at <https://www.planters.ae/blog/why-vertical-gardening-important>
- Rhoades, H. (2018). Using Chicken Manure Fertilizer in Your Garden. Retrieved on September 29, 2018 at <https://www.gardeningknowhow.com/composting/manures/chicken-manure-fertilizer.htm>
- Sumner, P., Hurst, W., Sparks, A., & Fonsah, E. (2010). Commercial Tomato Production Handbook. The University of Georgia. Cooperative Extension.
- Tilley, N. (2018). The Benefits of Manure Compost in Your Garden. Retrieved on January 24, 2019 at <https://www.gardeningknowhow.com/composting/manures/the-benefits-of-manure-in-your-garden.htm>
- Tomas, G. (2007). Rooting Depth Characterization of Tomato (*Lycopersicon esculentum* Mill). Central Luzon State University.
- Tomato Production Guide. TPG (2011). Tomato Production System. Retrieved on December 12, 2018 at <https://www.pinoybisnes.com/agri-business/tomato-production-guide/>
- Tufton, C. (2008). Protected Agriculture in Jamaica. The Ministry of Agriculture, Citizens Development Corps, and Partners of the Americas. Retrieved on September 26, 2018
- Usry, M. (2015). What is Soil Conditioner? Retrieved on September 29, 2018 at <https://www.southlandorganics.com/blogs/news/17989176-what-is-soil-conditioner>
- Vyas, K. (2018). Innovations That Could Revolutionize Agriculture. Retrieved on September 29, 2018 at <https://interestinengineering.com/13-vertical-farming-innovations-that-could-revolutionize-agriculture>
- Wright, S. (2011). Greenhouses and Similar Structures. University of Kentucky, College of Agriculture. Retrieved on September 28, 2018