https://doi.org/10.48196/020.01.2024.04

Submitted: November 14, 2023
Accepted: June 27, 2024

Development of a Single Row Paper Pot Transplanting System for Vegetables

Jeremy Charles S. Deanon[1], Fernando O. Paras, Jr.[2], Arthur L. Fajardo[3], and Kevin F. Yaptenco [4]

[1]Master of Science in Agricultural Engineering Graduate, Agri Biosystems Machinery and Power Engineering Division, Institute of Agricultural and Biosystems Engineering, College of Engineering and Agro-Industrial Technology, University of the Philippines Los Baños, 4031 College, Laguna, Philippines

[2]Professor 2, Agri Biosystems Machinery and Power Engineering Division, Institute of Agricultural and Biosystems Engineering, College of Engineering and Agro-Industrial Technology, University of the Philippines Los Baños, 4031 College, Laguna, Philippines

[3]Professor 5, Agri Biosystems Machinery and Power Engineering Division, Institute of Agricultural and Biosystems Engineering, College of Engineering and Agro-Industrial Technology, University of the Philippines Los Baños, 4031 College, Laguna, Philippines

[4]Professor 12, Agricultural, Food and Bio-process Engineering Division, Institute of Agricultural and Biosystems Engineering, College of Engineering and Agro-Industrial Technology, University of the Philippines, Los Baños, 4031 College, Laguna, Philippines

Email: [1]jsdeanon@up.edu.ph (Corresponding author); [2]foparas1@up.edu.ph, [3]alfajardo@up.edu.ph, and [4]kfyaptenco@up.edu.ph

ABSTRACT

To ease the situation of planting operations, this study developed a single-row paper pot transplanting system for vegetables. Trials were conducted to determine the rates of manual transplanting, paper pot making, arranging seedlings in paper pots, and mechanical transplanting. The manual transplanting rate was 84.20 plants/h to 113.30 plants/h (highest rate from transplanting cabbage). The manual paper pot-making rate was 57.08 pots/h to 68.41 pots/h (highest rate from 50.8mm-spaced pots). The machine-aided paper pot-making rate was 769.66 pots/h to 843.17 pots/h (highest rate from 50.8mm-spaced paper pot). The rate of arranging seedlings in paper pots was 34.98 plants/h to 36.80 plants/h (fastest rate from cabbage). The paper pot transplanting rate was 9,391 plants/h to 14,882 plants/h (fastest rate from spinach). Respondents accepted the paper pot transplanter. Using a paper pot transplanter, the return on investment is 90.16%. Mechanization results in an additional cost (machine and paper pots), nonetheless, farmers' field exposure time during planting has been reduced by about 99% and the ergonomics of using paper pot transplanter ease the condition of planting operations of farmers. Paper pot design and transplanter modifications were suggested to further improve the paper pot transplanting system.

Keywords: *Paper pot, vegetables, transplanting, mechanization*

INTRODUCTION

Vegetables are an important crop in Southeast Asia, with large production areas and high annual yields. In the Philippines, the vegetable industry shows an increasing trend in value with PhP 42,324 million in 2011 which increased to PhP 77,132 million in 2020 (DA-HVCDP, 2022. Philippine Vegetable Industry Roadmap 2021-2025). Meanwhile, mechanization improves yields and timeliness of operation, lowers agricultural losses, boosts farming efficiency, boosts total output, and enhances increasing cultivation intensity and optimizing economic scale, contributing to an improved farming overall business venture ((Rodulfo, et al, 2021).

Vegetables can also be grown in a variety of ways, but most commonly, it is either grown by direct seeding or transplanting. Plants established by transplanting are more uniform, can tolerate or escape early environmental/biological stresses, and can achieve earlier maturity than direct-seeded plants (Liptay et al., 1982, as cited by Leskovar, Daniel, 1993). Additionally, transplanting using the "paper pot system," combines a specially made paper container (tube or "pot"), tools for filling and seeding it, methods for nurturing seedlings, tools for transplanting, and field cultural practices.

Cultivation in the Philippines lags in terms of mechanization of transplanting and harvesting operations. Human power at an average of 56.53%, still leads farm operations. The level of mechanization stands at 1.68 hp/ha in terms of available power which is relatively low compared to other neighboring countries. (Rodulfo, et al, 1998). Several transplanters and tools are used for proper transplanting, and design depend on the type of seedling crop (Kumar and Raheman, 2011). Seedling transplanting is a crucial operation in the vegetable production value chain which is laborious, time-consuming, and ineffective when performed manually (Khadatkar et al., 2018). Additionally, labor shortages cause delays in transplanting during the agricultural peak season, resulting in a drastic reduction in yields (Bhatt et al., 2016). The use of vegetable transplanters, as a mechanized vegetable production, might be a solution to address these vegetable cultivation challenges (Diao et al., 2016). A comparatively flexible method for commercial vegetable growing is offered by the paper pot system (Robb et al, 1994).

A linked paper pot or a chain of pots prepared by connecting a series of paper pots is made by joining two-ply sheets of paper with water - resistant adhesive (Nambu and Tanimura, 1992).

Developed in Japan, the paper pot transplanting system is an innovative, labor-saving technology. It feeds itself through the transplanter which relies using paper pots that are connected in a chain. A narrow furrow shall be opened by the transplanter, the paper chain goes down into the furrow, and then the plants are covered by a set of metal flanges. The in-row spacing is pre-determined because the pots are in a chain. (Hendrickson, 2010). Studies have shown how it can drastically reduce the time and effort required for moving while also increasing work proficiency and potentially increasing harvest production. The paper pot transplanter has significant promise for improving horticulture operations, even though more research may be required to determine its practicality for varied yields and cultivating circumstances. (Jayaprakash, R., et al., 2023).

According to Paras, F. et al (2006), there is no assurance of technology transfer due to the different situations and conditions related to the popularization and dissemination of technologies. Problems and experiences associated with the extension of such technologies, strategies, and other possible approaches, that could aid in penetrating the barriers toward small farm mechanization in the Philippines, are discussed.

OBJECTIVES

The general objective of the study was to create a paper pot transplanting method for vegetables to make farming operations easier for farmers.

Specifically, the study aimed to:

1. Develop a paper pot specifically for closely spaced vegetables;

2. Develop a single-row transplanter for vegetables;
3. Conduct performance testing and evaluation of the designed transplanter;
4. Conduct farmer feedback acceptability for the paper pot transplanting system; and
5. Conduct of simple cost-benefit analysis of the paper pot transplanter.

During the time of the study, the COVID-19 pandemic had started which made transportation, access to facilities, and equipment limited.

METHODOLOGY

Manual Transplanting

For the manual transplanting preliminary activity, amaranth spinach amaranth, romaine lettuce, and Chinese white cabbage or black behi pechay seedlings in a 128-hole seed tray were bought from the market

The seedlings were 14 days after planting (DAP) and manually transplanted, and the transplanting rate was determined using **Equation 1**.

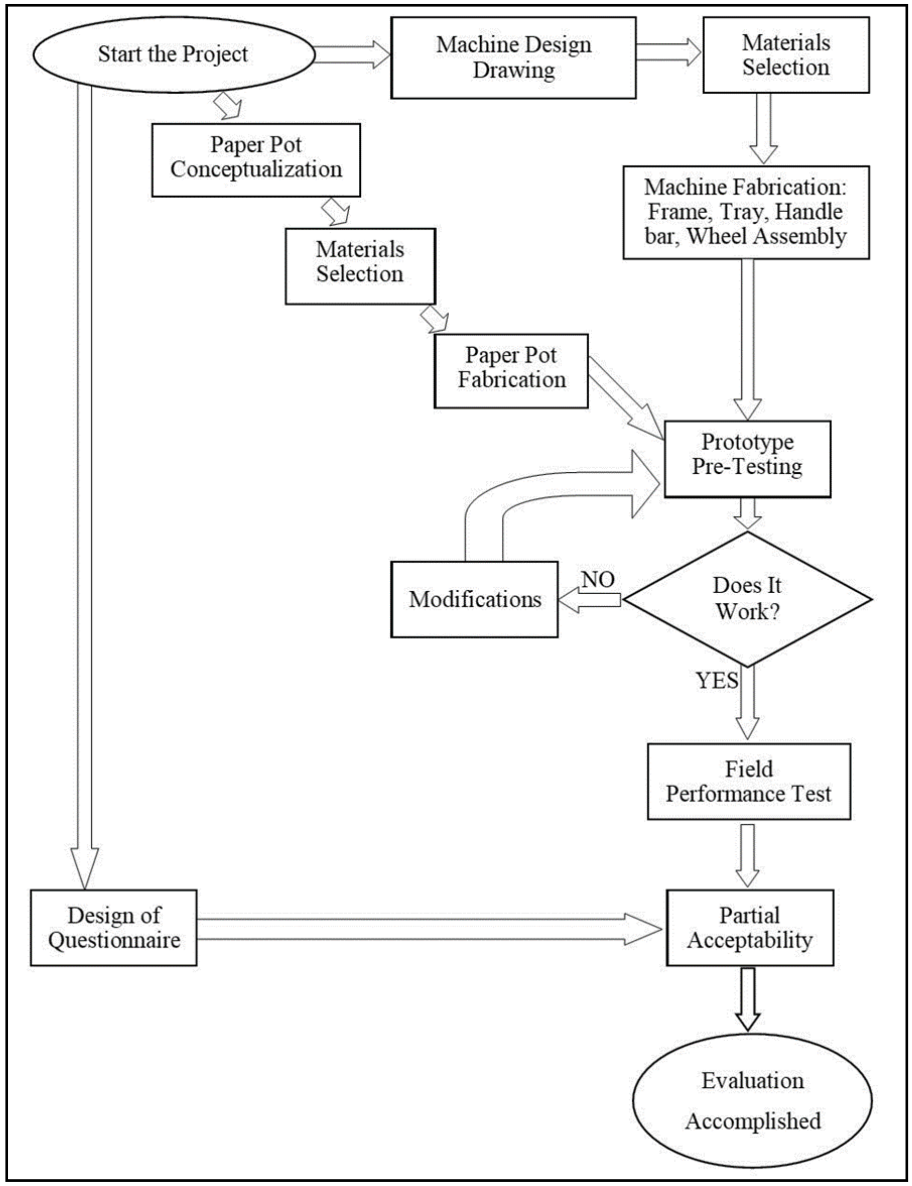

Figure 1. Process flow chart for the paper pot transplanting system.

$$\text{transplanting rate} = \frac{no.\, of\ plants}{time\ (h)} \quad \textbf{\textit{Equation 1}}$$

Figure 1 shows the process flow for the paper pot transplanting system, from the start to completion of the study. These include the conceptualization of the paper pot, fabrication of the paper pot transplanter, and design of the questionnaire. Afterward, pre-testing, modification, field test, and farmer feedback acceptability survey were done to accomplish the evaluation. Proper materials were selected for the fabrication of the machine.

Paper Pot-Making Process

Initially, paper pots were made manually using 2 rolls of 44-mm wide thermal paper bonded together using a common glue. The paper pot-making rate was recorded. Spacing considered for the paper pot was 50.8mm, 63.5mm, and 76.2mm, based on existing commercialized Paperpot Co transplanter and reviews. The paper pot's opening for soil and seedlings is 25mm, based on the size of holes in a 128-hole seed tray.

Semi-automatic paper pot-making machine

There were 2 rolls of thermal paper in the paper holder where the ends were pulled all the way to the manually rotated crank. When rotated once, the crank extrudes an overlap of 2 sheets of 25.4mm-long thermal paper. In the center, the manual lever for glue dipping moved upward and downward and was parallel to the glue bath. During paper pot making, the crank was rotated based on pot spacing and glue dipping level moves to create a slot for seedlings.

Paper Pot Transplanter

The paper pot transplanting machine design was mainly based on the existing commercialized Paperpot Co transplanter design, with minor adjustments in its dimensions and materials used. All parts were sourced locally. The fabricated paper pot transplanter is shown in **Figure 2.**

Vegetable seedlings and paper pots were made ready for transplanting. Philippine Agricultural Engineering Standards for Seeder and Planter Planter (PNS/PAES 122:2001 and PNS/PAES 123:2001), the nearest applicable standard, was the basis for testing the machine. To obtain actual data on overall machine performance, a field performance test is carried out.

Performance Evaluation

The paper pot transplanter for vegetables was tested in a cultivated area of a small farm lot. The transplanting rate was obtained by recording the number of plants transplanted in a 10-meter plot and the time spent. The transplanting rate was computed using **Equation 1.**

Statistical Tools for Farmer Feedback Acceptability Evaluation

Statistical tools including frequency count, Likert-scale, and median were utilized for the statistical treatment of data.

Cost-benefit Analysis

The mechanization cost of using the paper pot transplanting system was compared to the traditional planting method. Also, the benefits of using the paper pot transplanting system were evaluated further.

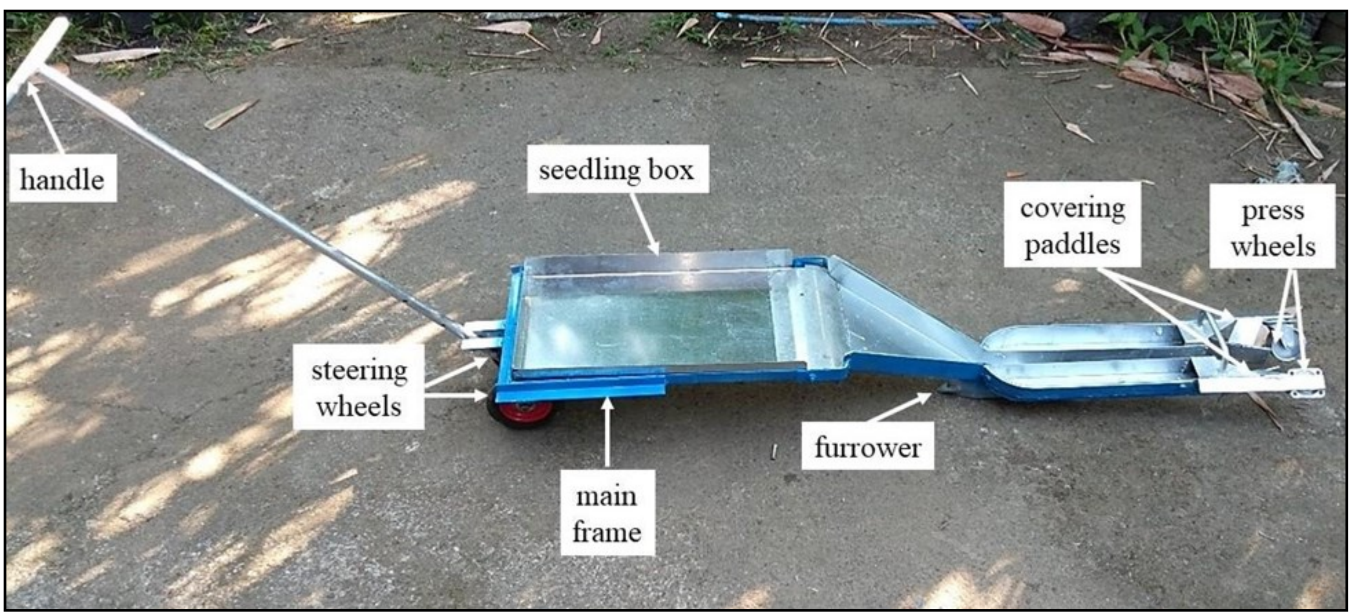

Figure 2. Fabricated paper pot transplanter.

RESULTS AND DISCUSSIONS

Manual Transplanting

Transplanting of spinach, lettuce, and cabbage was done manually. The average rate of manual transplanting of vegetables is shown in **Figure 3**. Transplanting cabbage had the fastest average transplanting rate (113.30 plants per hour) while transplanting spinach had the slowest average (84.20 plants per hour). As the plant space increases, the transplanting rate also increases. The lesser time of repeated standing and bending position made an increase in transplanting rate.

Manual Making of Paper Pot

Making paper pots for vegetables were done manually. The average rate of manual making of paper pots, at different spacing can be seen in **Figure 4.** The fastest rate (68.41 pots per hour) was achieved by making paper pots with 50.8mm spacing while the slowest rate (57.08 pots per hour) was obtained by making paper pots with 76.2mm spacing. Results showed that, as the plant space increases, the rate of making paper pots decreases, and also, the closer the space between the pots, the greater the number of pots can be made per unit length.

Semi-automatic paper pot-making machine

A semi-automatic paper pot-making machine, with major parts fabricated from a 3D printer machine, was assembled (**Figure 5**). The same plant spacing was considered for the paper pot-making machine, which is 50.8mm, 63.5mm, and 76.2mm. Openings for seedlings were similar to a manually-made paper pot, which was 25mm. It was also made from a 44mm-width thermal paper with common school glue used as an adhesive to bond thermal papers.

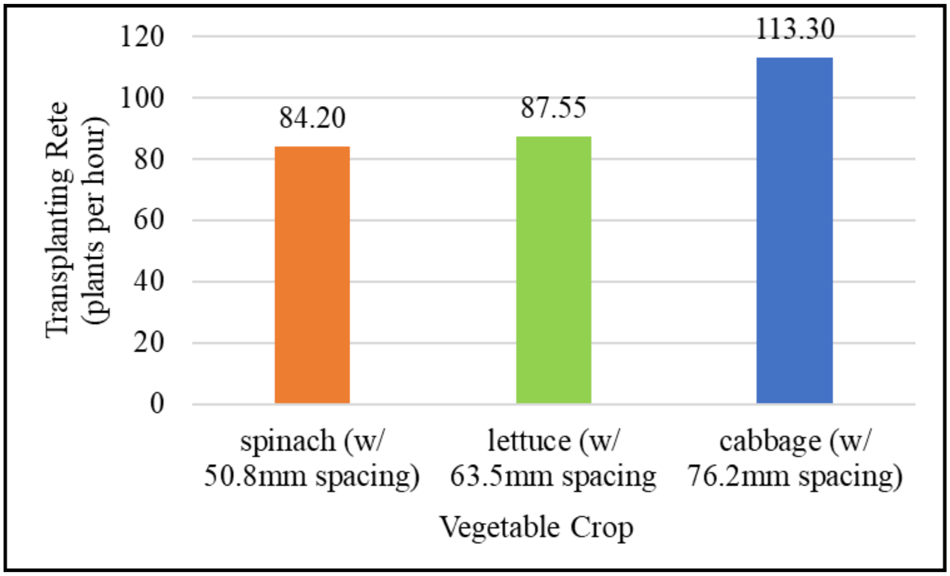

Figure 3. The average rate of manual transplanting of vegetables.

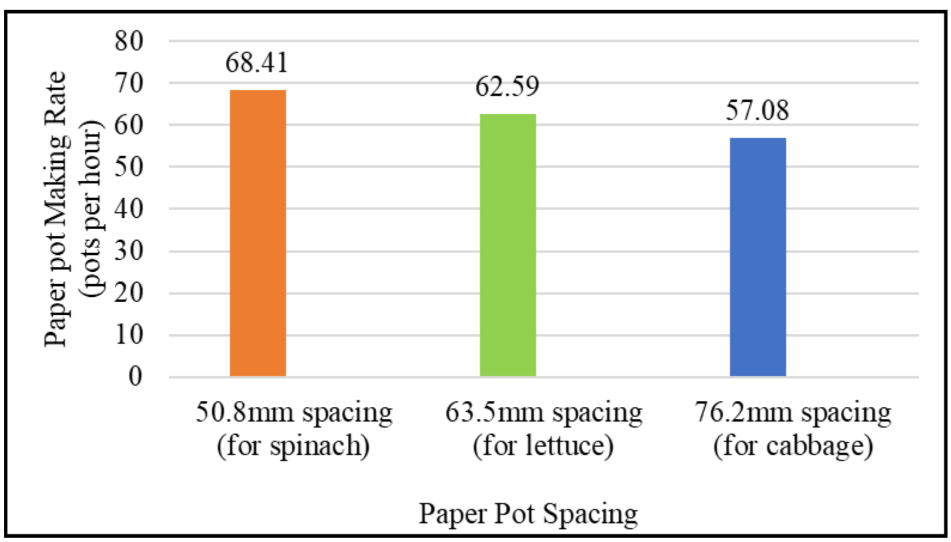

Figure 4. Rate of manually-made paper pot making at different spacing.

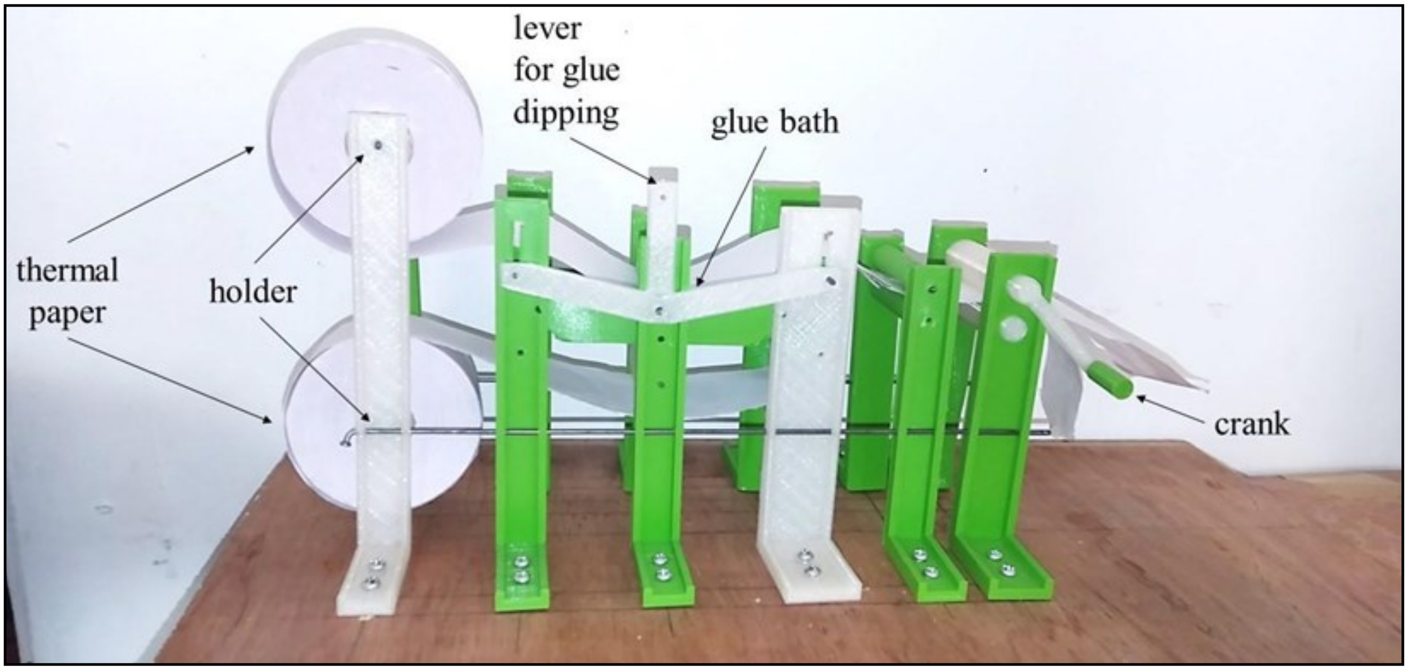

Figure 5. Fabricated prototype paper pot maker.

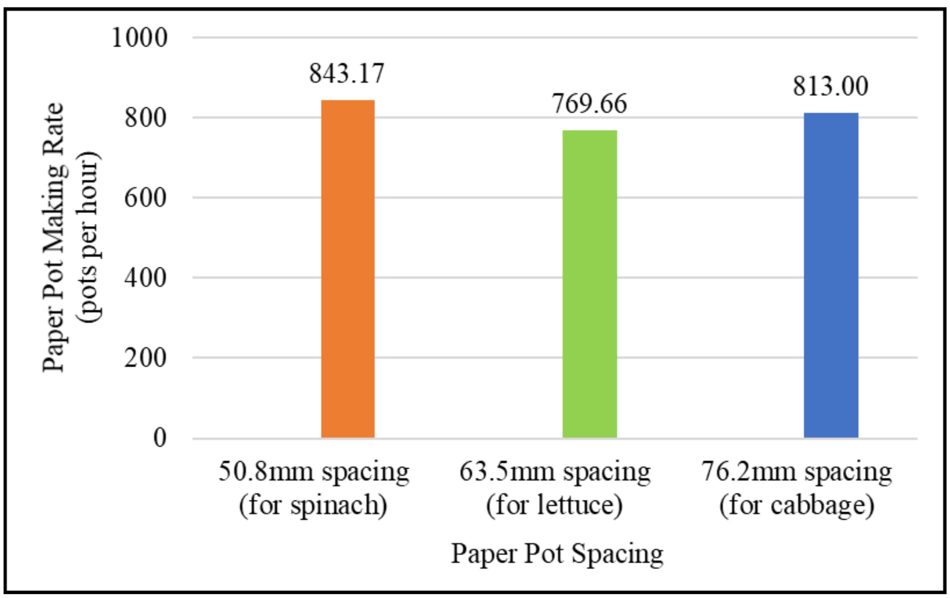

Figure 6. The average rate of making a paper pot with the aid of a machine.

Testing of a Prototype Paper Pot Making Machine

Making of paper pots for vegetables were made with the aid of a machine. **Figure 6** shows the average rate of making a paper pot with the aid of a machine. The fastest average rate (843.17 pots per hour) was a paper pot with 50.8mm spacing while the average slowest rate (769.66 pots per hour) was a paper pot with 63.5mm spacing for transplanting. Comparing the rate of manual making of paper pots (57.08 to 68. 41 pots per hour) to the rate of making paper pots with the aid of a machine (769.66 to 843.17 pots per hour), the rate of paper pot making increased by about 1,218% to 1,391%.

Arranging Seedlings in Paper Pots

Arranging of vegetable seedlings in paper pots was done manually. Selected vegetables were spinach with 50.8mm plant spacing, lettuce with 63.5mm plant spacing, and cabbage with 76.2mm plant spacing. **Figure 7** shows the average rate of seedling arranging (plants per hour) in paper pots. The fastest average arranging rate was the cabbage (36.8 plants per hour) while the slowest average arranging rate was spinach (34.98 plants per hour). As the plant space was increased, the rate of arranging vegetable

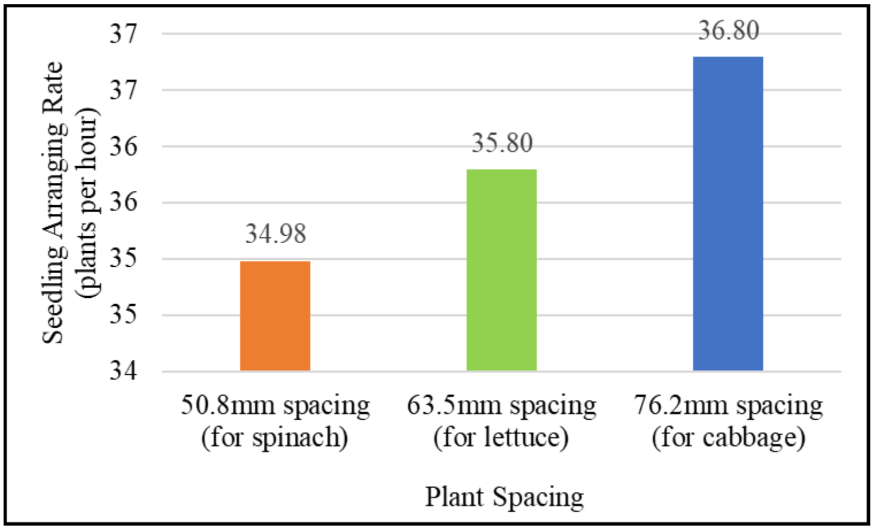

Figure 7. The average rate of arranging spinach, lettuce, and cabbage seedlings in a paper pot.

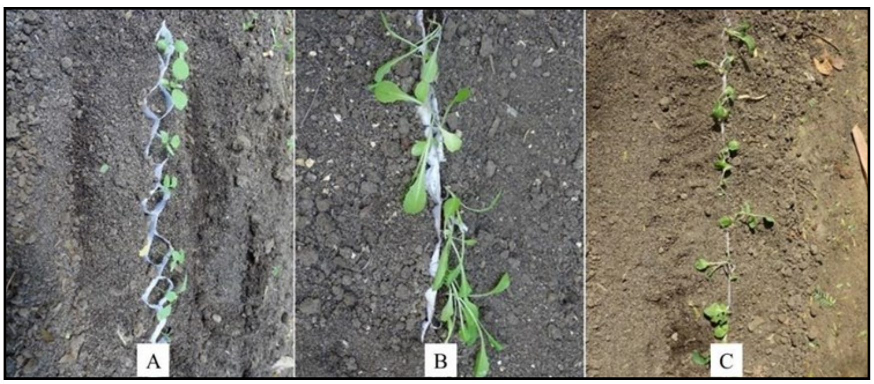

Figure 8. Transplanted spinach (A), lettuce (B), and cabbage (C) using a paper pot transplanter.

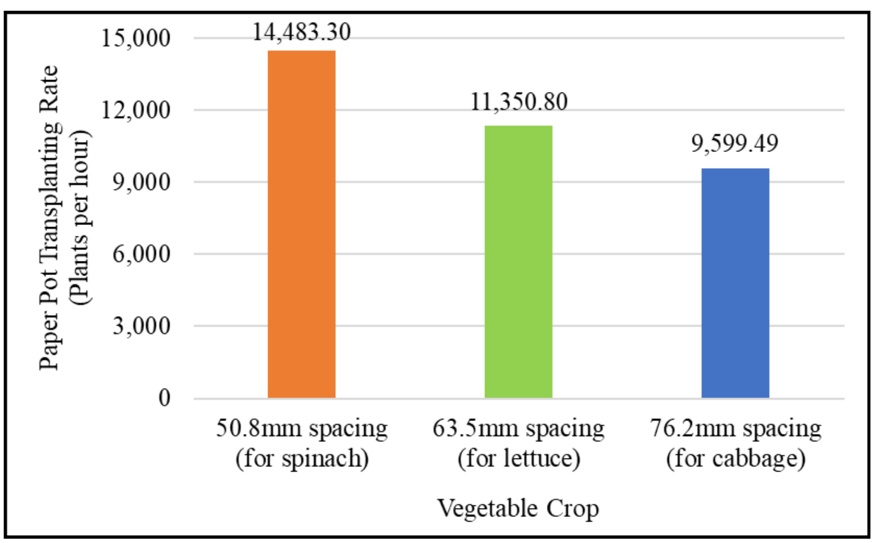

Figure 9. The average rate of transplanting using the paper pot transplanter.

seedlings increased. A lesser number of plants for more plant space results in a faster rate of arranging seedlings.

Paper Pot Transplanting

Transplanting of vegetable seedlings in paper pots was done using the fabricated paper pot transplanter (**Figure 8**). Through observation, closely spaced seedlings (A) are planted more upright than seedlings that are spaced further apart (B and C).

The average rate of transplanting using a paper pot transplanter is shown in **Figure 9.** The fastest transplanting rate (14,882 plants per hour) was transplanting spinach (50.8mm spacing) while the slowest transplanting rate (9,391 plants per hour) was transplanting cabbage (76.2mm spacing). The observed pattern is logical because there are more plants per unit length of the prepared paper pots. The lesser the space between plants, the greater the transplanting rate.

Comparison of Average Rate of Transplanting for Manual Transplanting and Paper Pot Transplanting

The fastest average transplanting rate (14,483.30 plants per hour) was transplanting spinach using a paper pot transplanter, while the slowest average transplanting rate (84.20 plants per hour) was manual transplanting of spinach (**Figure 10**).

It takes 2.33 hours to transplant seedlings manually, 2.57 hours to make paper pots manually, 4.53 hours to arrange seedlings in paper pots, and 0.01 h to transplant.

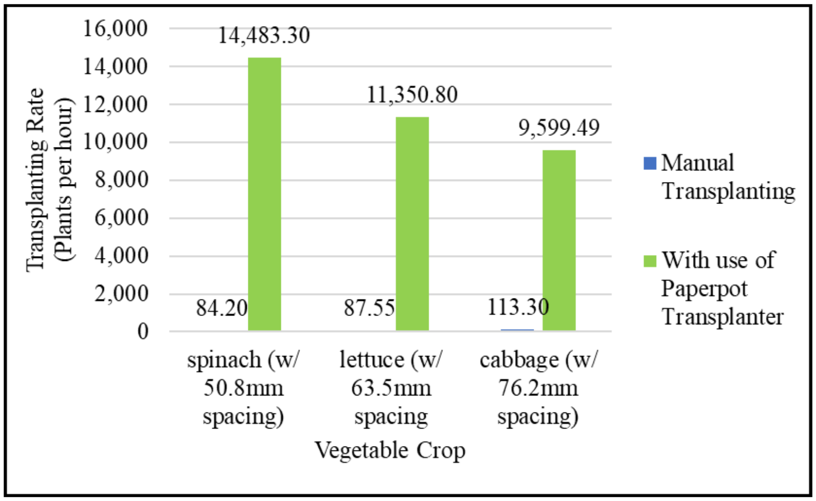

Figure 10. Comparison of average transplanting rate of spinach, lettuce, and cabbage with manual transplanting and paper pot transplanting.

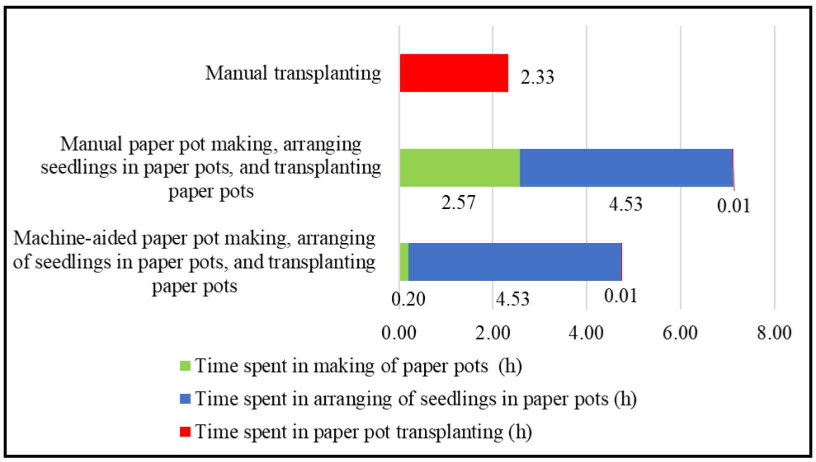

Figure 11. Time spent in transplanting seedlings in 10-meter plots with different transplanting methods.

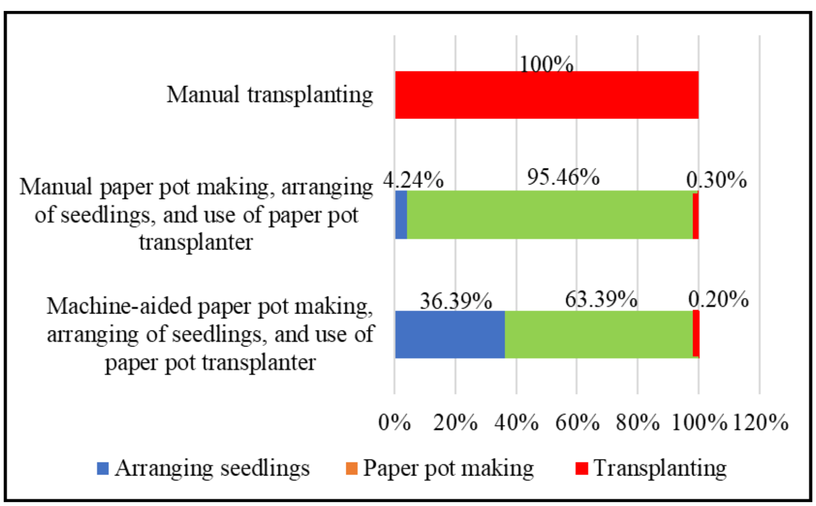

Figure 12. Percentage of time spent in preliminary activities and transplanting.

Meanwhile, with the aid of paper pot maker and use of paper pot transplanter, it takes 2.57 hours to make a paper pot with the aid of a machine, 4.53 hours to arrange seedlings in paper pots, and only 0.1 hours to transplant (**Figure 11**).

In manual transplanting, a farmer is exposed to hard work, and an uncomfortable environment 100% of the time. In manual paper pot making and use of paper pot transplanter, 63.39% of the time was arranging seedlings in paper pots, 36.39% of the time was manually making paper pots, and only about 0.20% of the time for transplanting. On the other hand, with the aid of a paper pot maker and the use of a paper pot transplanter, 95.46% of the time was arranging seedlings in paper pots, 4.24% of the time was making paper pots, and only about 0.30% of the time was transplanting (**Figure 12**).

The farmer's field exposure time during planting has been reduced by about 99% with the developed transplanting system. Furthermore, the ergonomics of transplanting operation using the transplanter as against manual transplanting may be viewed as an additional benefit that would contribute to easing the condition of planting operations of farmers.

Farmer Feedback Acceptability

In this part of the study, a brief background of the design of the single-row paper pot transplanter for vegetables was discussed with the vegetable farmers. Also, a short video clip about paper pot transplanting was shown. After which, a farmer feedback acceptability survey was made. There were thirty (30) vegetable farmer respondents at Brgy. Mataddi, Nagtipunan, Quirino.

Demographics

Figure 13 presents the distribution of respondents according to their gender and

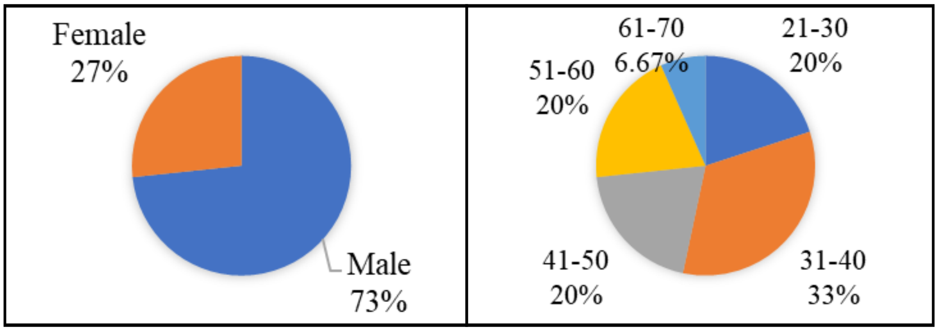

Figure 13. Distribution of respondents by gender and by age group.

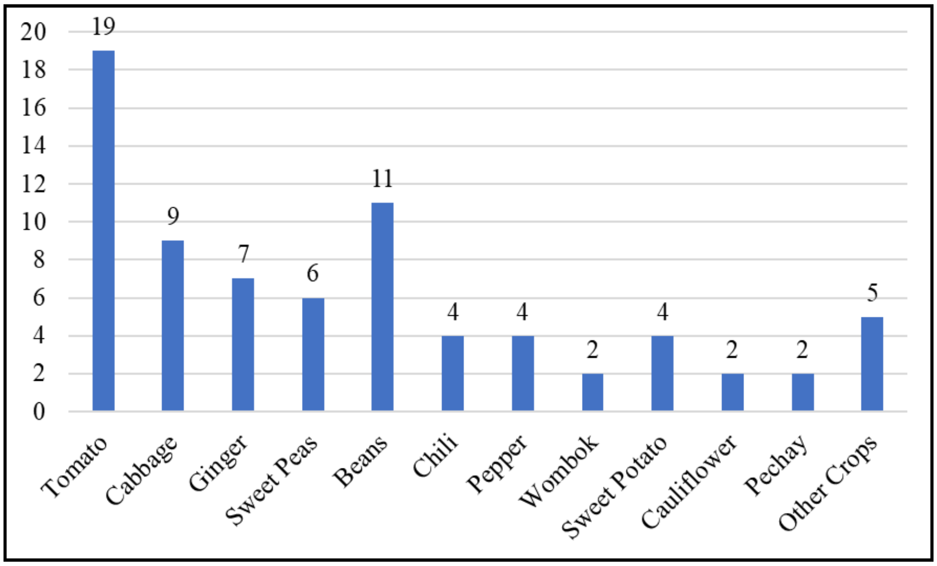

Figure 14. Crops planted by the farmers.

Table 1. Level of agreement of the farmers to the acceptability of the vegetable transplanter which uses paper pots.

QUESTIONS	MEDIAN	INTERPRETATION
Q1	4	Agree
Q2	3	Undecided
Q3	4	Agree
Q4	3	Undecided
Q5	4	Agree
Q6	4	Agree
Q7	3	Undecided
Grand Median	4	Agree

age group. In terms of gender, the majority of the survey's respondents are male (73%) and 27% female respondents. In terms of age, 33% are 31-40 years old, 20% are 21-30, 41-50, 51-60 years old, and 7% are 61-70 years old.

Type of crops planted

Most respondents planted tomatoes on their farms, as seen in **Figure 14.** Several farms also planted beans, cabbage, ginger, and sweet peas. Other common crops planted by the farmers include chili, pepper, wombok, sweet potato, cauliflower, and pechay.

Acceptability analysis

Generally, it can be observed from **Table 1** that respondents have a positive agreement with the level of acceptability of the vegetable transplanter which uses paper pots (Grand Median = 4). Amongst measures of central tendency, the 'median' was preferred to be used in the analysis since it is less affected by outliers, and skewed data than the mean, and the distribution is asymmetrical.

Specifically, respondents agreed with their dissatisfaction with their current planting practices (Q1), as stated by data collected from respondents. On the other hand, despite their dissatisfaction with their current planting practices, it appears that the respondents were undecided regarding the need for vegetable transplanter to aid their current planting practices (Q2). Most of

Figure 15. Manual transplanting (A) and transplanting using a paper pot transplanter (B).

the respondents' remarks or reasons focused on the condition of their farm areas which are mostly sloping and small in size (0.03 – 1.5 hectares).

Furthermore, respondents agreed that the use of paper pots on vegetable transplanter works well (Q3) but they were uncertain if the said machine is better than manual transplanting (Q4). The same reason as discussed above was seen behind the respondents' uncertainty. In addition, the respondents agreed with the idea that vegetable transplanter which uses paper pots is fit for the physical setup of a farm lot (Q5) and they are willing to use the said machine (Q6).

Nevertheless, the respondents were undecided on the ease of assembly or repair of the vegetable transplanter which uses paper pots as of the date of the interview.

Ergonomics

With regards to ergonomics, seemingly, the paper pot transplanting machine was easy to operate and provided a more ergonomic position than the manual transplanting method (**Figure 15**). However, the paper pot transplanting system requires preparation time before going to the field, which can be done in a more comfortable environment, not on the field.

The impact of paper pot transplanting technology can be viewed as an opportunity for farm workers to transition from simply hired labor for planting to producers of paper pots and seedlings in paper pots. According to the International Labour Organization (2019), historically, the number of jobs created has outstripped the number of jobs eliminated as technology has changed the way work is done. Also, the paper pot transplanting system would open up demands for designers, fabricators of the transplanting machine, and paper pot-making machine. Adoption of the paper pot transplanting system can also improve the farmer's productivity. The farmers can work on other economically important activities which consumes their time for manual transplanting.

Cost-benefit analysis

The conduct of cost-benefit analysis can be an evaluation for economic benefit. It compares the cost of a project or decision with its expected benefits and helps decision-makers assess whether the benefits of a particular action or investment outweigh the costs associated with it.

The comparison of transplanting cost using the manual method and the use of a paper pot transplanter is shown in **Table 2**. The return on investment was 104.25% with the traditional method, and 90.16% with the use of a paper pot

Table 2. Cost and return analysis of traditional (manual) planting and using manual method and mechanized (using paper pot transplanter) in 1 hectare.

	TRADITIONAL	MECHANIZED
Revenue		
Sales of produce (20MT @ PhP20/kg.	400,000.00	400,000.00
Total Revenue	**400,000.00**	**400,000.00**
Expense		
Labor cost		
Land Preparation		
Cleaning the area	10,000.00	10,000.00
Digging and plot preparation	12,500.00	12,500.00
Making holes/ furrows	5,000.00	5,000.00
Fertilizer application	5,000.00	5,000.00
Mixing fertilizer	5,000.00	5,000.00
Planting (labor)	6,250.00	1,000.00
Care and Maintenance		
Irrigation	17,500.00	17,500.00
Crop protection	22,500.00	22,500.00
Weeding	6,250.00	6,250.00
Side-dressing & hilling up	10,000.00	10,000.00
Roughing	2,250.00	2,250.00
Harvesting	3,750.00	3,750.00
Cleaning	3,750.00	3,750.00
Sub-Total	**109,750.00**	**104,500.00**
Material Cost		
Seeds	500.00	500.00
Fertilizers		
Chicken Dung	12,000.00	12,000.00
Triple 14	13,600.00	13,600.00
Insecticide	10,000.00	10,000.00
Fungicide	8,000.00	8,000.00
Paper pots		18,785.00
Sub-Total	**44,100.00**	**62,385.00**
Fixed Cost		
Land Rent	30,000.00	30,000.00
Depreciation on tools and equipment	985.00	985.00
Depreciation on paper pot transplanter		1,477.15
Sub-Total	**30,985.00**	**32,462.15**
Miscellaneous		
Packing material	1,000.00	1,000.00
Transportation	10,000.00	10,000.00
Sub-Total	**11,000.00**	**11,000.00**
Total Cost of Production	**195,835.00**	**210,347.15**
Total Expense	**195,835.00**	**210,347.15**
Net Income	**204,165.00**	**189,652.85**
Return on Investment	**104.25**	**90.16**

transplanter.

There are additional costs for the machine and paper pots when using a paper pot transplanting system. The farmer's field exposure time during planting has been reduced by about 99% with the developed transplanting system. Furthermore, the ergonomics of transplanting operation using the transplanter as against manual transplanting may be viewed as an additional benefit that would contribute to easing the condition of planting operations of farmers.

CONCLUSION

The development of a paper pot transplanting system was conceptualized. Preliminary activities included the manual transplanting of vegetables, the manual making of paper pots for vegetables, and development of a machine that aids in making paper pots for vegetables, and the development of a single-row paper pot transplanter prototype.

In manual transplanting, the fastest transplanting rate was observed for cabbage while the slowest recorded transplanting rate was for spinach. It was observed that the rate of manual transplanting of farmers was mainly dependent on the required spacing of planting. This dictates the number of times the farmers would have to execute the manual planting operation.

In manual assembling of paper pots, the fastest paper pot-making rate was observed for a 50.8 mm-spaced paper pot while the slowest paper pot-making rate was recorded for a 76.2 mm-spaced paper pot. It was observed that the closer the spaces between the pots, the faster the rate of making paper pots. Also, there would be more pots per unit length for vegetables that needed to be closely spaced.

On the other hand, with machine-aided paper pot making, the fastest paper pot-making rate was recorded for a 50.8mm-spaced paper pot while the slowest paper pot-making rate was observed for a 63.5mm-spaced paper pot. Similarly, it was noted that the rate of making paper pots would be faster for closely-spaced paper pots, as there would be more pots per unit length.

It was observed that machine-aided paper pot-making improved the rate (1,218% to 1,391%) by which paper pots are made. This significantly reduced time in making paper pots.

With regards to arranging seedlings in paper pots, the fastest arranging rate was noted for cabbage while the slowest arranging rate was recorded for spinach. It was observed that it was easier to arrange the seedlings when there were greater spaces between the pots, hence a faster rate was recorded for vegetable seedlings that have wider spacing requirements.

For the field testing of the single-row paper pot transplanting prototype, the fastest transplanting rate was recorded for spinach while the slowest transplanting rate was noted for cabbage. Logically, a faster planting rate would be observed for plants that require paper pots with smaller spacing. More seedlings would be planted per unit length due to the closely spaced seedlings in the paper pots.

For the farmer feedback acceptability, the respondents have a positive agreement with the level of acceptability of the vegetable transplanter which uses paper pots. Specifically, respondents agreed with the statement of dissatisfaction with their current planting practices and are undecided regarding the need for vegetable transplanter to aid their current planting practices. Respondents agreed that the use of paper pots on vegetable transplanter works well, but they are uncertain if the said machine is better than manual transplanting. In addition, the respondents agreed that a vegetable transplanter that uses paper pots applies to the physical setup for vegetable farms and that they are willing to use the machine.

For the cost-benefit analysis, the return on investment was 104.25% with the traditional method, and 90.16% with the use of a paper pot transplanter. There are additional costs for the machine and paper pots when using the paper pot transplanting system. Furthermore, there would be additional labor for the preparation of paper pots and transferring of seedlings to the paper pots. However, the additional costs for the adoption of the paper pot transplanting system may be justified by the non-economic benefits.

In this study, it was established that the farmer's field exposure time during planting has been reduced by about 99% with the developed transplanting system. Also, the ergonomics of transplanting operation using the paper pot transplanting system as against manual transplanting can be realized as an additional benefit that would contribute to easing the condition of planting operations of farmers.

RECOMMENDATIONS

Considerable time is devoted to arranging and transferring seedlings to the paper pots. A paper pot that does not disintegrate easily and could act as the growing cup for the seedlings, replacing the need for seedling trays, could further improve the system. Also, having a paper pot material that would provide nutrients or serve as fertilizer throughout the growing period of the seedlings might contribute to a better plant survival rate and yield. In addition, having a paper pot design that could accommodate widely-spaced vegetables could be considered. Design improvements on the transplanter that may be studied further could include steering capability, multiple row system, and self-propelled or tractor-mounted versions.

ACKNOWLEDGEMENTS

The authors would like to thank the Department of Science and Technology - Engineering Research and Development for Technology (ERDT) for the financial support of this project and the Mattadi Farmers Association for their valuable contributions during the consultation and demonstration of the developed technology.

LITERATURE CITED

BHATT, R., S. S. KUKAL, M. A. BUSARI, S. ARORA, and M. YADAV. 2016. Sustainability issues on rice-wheat cropping system. Journal of International Soil and Water Conservation Research 4:84-74.

DA-HVCDP. 2022. Philippine Vegetable Industry Roadmap 2021-2025. http://www.pcaf.da.gov. ph/wp-content/uploads/2022/06/Philippine-Vegetable-Industry-Roadmap-2021-2025.pdf. Accessed (June 8, 2023).

DIAO X., SILVER J., H. TAKESHIMA, AND J. SILVER. 2016. Agricultural mechanization and agricultural transformation. IFPRI Discussion Paper 01527. African Transformation Report 1-56.

HENDRICKSON, J. 2010. Paper-Pot System for Transplanting Efficiency. https://newenglandvfc.org/sites/newenglandvfc.org/files/content/proceedings 2009/PaperPot.pdf. Accessed (January 12, 2019).

JAYAPRAKASH, R., J. KALAIVANI, and S. PRATHIBA. 2023. Development of Paper Pot Based Transplanter. International Research Journal of Modernization in Engineering Technology and Science. Volume:05. Issue:03. March 2023.

KHADATKAR, A., S. M. MATHUR, and B.B. GAIKWAD. 2018. Automation in Transplanting: A Smart Way of Vegetable Cultivation. Current Science, 115(10), 1884–1892.https://www.jstor.org/stable/26978519.

KUMAR, G. V. P. and H. RAHEMAN. 2008. Vegetable Transplanters for Use in Developing Countries—A Review. International Journal of Vegetable Science. Volume 14. Issue 3. pp.232-255.

KUMAR G.V.P. and H. RAHEMAN. 2011. Development of a walk-behind type hand tractor-powered vegetable transplanter for paper pot seedlings. Biosystems Engineering 110:189-197.

LIPTAY, A., E.F. BOLTON, AND V. A. DIRKS. 1982. A Comparison of Field-Seeded and Transplanted Tomatoes grown on a clay soil. Can. J. Plant Sci. 62:483-487.

LESKOVAR, DANIEL and D. CANTLIFFE. 1993. Comparison of Plant Establishment Method, Transplant, or Direct Seeding on Growth and Yield of Bell Pepper. Journal of the American Society for Horticultural Science. American Society for Horticultural Science. 118. 10.21273/JASHS.118.1.17.

NAMBU, T., and M. TANIMURA. 1992. Development of automatic transplanter using chain pot for vegetable crops. In International Symposium on Transplant Production Systems 319. July 1992. pp. 541-546.

PARAS, F.O., AMONGO, R. M. C., and AMONGO, C. (2006). Technology Transfer Strategies for Small Farm Mechanization Technologies in The Philippines. ResearchGate. https://www.researchgate.net/publication/266882585_TECHNOLOGY_TRANSFER_STRATEGIES_FOR_SMALL_FARM_MECHANIZATION_TECHNOLOGIES_IN_THE_PHILIPPINES/figures?lo=1. Accessed (June 8, 2023).

PNS/PAES 122:2001 Agricultural machinery - Seeder and Planter – Specifications by Philippine Agricultural Engineering Standards.

PNS/PAES 123:2001 Agricultural machinery - Seeder and Planter – Methods of Tests by Philippine Agricultural Engineering Standards.

ROBB, J. G., SMITH, J. A., WILSON, R. G., and C. D. YONTS. (1994). Paperpot transplanting systems—overview and potential for vegetable production. Hort Technology, 4(2), 166-171.

RODULFO, V. A., R.M.C. AMONGO and M.V.L. LARONA. 1998. Status of Philippine agriculture mechanization and its implication to global competitiveness. In Philippine Agricultural Mechanization Bulletin.Vol.V No.1.CEAT-UPLB. p.3-13.

RODULFO JR, V. A., A. A. DEL ROSARIO, M. V. LARONA, A. SALANDANAN, M.G. BAUTISTA, AND N. J. V. QUERIJERO. (2021). Effects of the Extensive Use of Mechanization on Farm Labor Use and Patterns in Rice and Corn Production Systems in the Philippines. Philippine Journal of Agricultural and Biosystems Engineering, 17 (2). ■