

The 11th Asian-Australasian Conference on Precision Agriculture (ACPA 11)  
October 14-16, 2025, Chiayi, Taiwan

## ENHANCING SUSTAINABLE FARMING OF NH: MECHANIZATION OF PLANTING AND POST HARVEST CLEANING

Somnath Kale<sup>1</sup>, Cong-Chuan Pham<sup>1</sup>, Chih-Ming Hsu<sup>1</sup>,  
An-Pan Cherng<sup>2</sup>, Wei-Chih Lin<sup>1\*</sup>

<sup>1</sup> Department of Mechanical and Electro-Mechanical Engineering, National Sun Yat-sen  
University, Kaohsiung City, Taiwan.

<sup>2</sup> Department of Biomechatronic Engineering, National Ilan University, Yilan City, Taiwan.

\*Corresponding Author: wc.lin@mail.nsysu.edu.tw

### ABSTRACT

*Nymphoides hydrophylla* (NH), commonly known as white water snowflake, is a culturally and nutritionally important aquatic vegetable, particularly valued in Taiwan's Hakka communities. However, its commercial scalability remains limited due to labor-intensive practices in both planting and post-harvest cleaning. This study introduces an integrated mechanized system that combines a seedling planting tool and a cleaning machine, designed to enhance overall production efficiency, reduce manual labor, and ensure consistent product quality. Field trials of the planting component were conducted at the Qishan water snowflake farm in Kaohsiung. The mechanized planter achieved a seedling ejection rate of 92-99% and a planting speed of 2.3 s per row (6 positions). The number of nodes per planting unit ranged from 6.1 to 12.0, surpassing the minimum target despite variability (CV: 41-63%). These results indicate that the machine can deliver sufficient seedling density with tunable performance to optimize planting efficiency and resource use. For post-harvest processing, the cleaning component of the system significantly reduced labor requirements from 29 to 19 workers per ton representing a 34.5% reduction. The most substantial improvement was in the rough cleaning stage, where labor dropped from 16 to 6 workers. Total processing time was reduced from 11.0 to 8.7 h, due to a 57.5% reduction in rough cleaning time. Fine cleaning and other operations maintained consistency in quality and hygiene standards.

This study provides a sustainable and scalable approach to NH cultivation by combining mechanized planting and cleaning into a single production system. Local farmers and customers eventually benefit from the system's increased production, decreased reliance on labor, and promotion of wider commercialization.

**Keywords:** *Nymphoides hydrophylla* (NH), agricultural mechanization, labor reduction, sustainable agriculture.

### 1. INTRODUCTION

The world's population is expected to exceed ten billion by 2050, increasing pressure on global food production systems (Abelti et al., 2023). Given this difficulty, it is essential to investigate

alternate dietary sources, such as underutilized aquatic plants, which may help with the world's food supply. Among these, *Nymphoides hydrophylla* (NH), often known as "white water snowflake," is an aquatic vegetable that has become a significant food source, especially for the Hakka people of Taiwan (Ko, Huang, and Ng, 2014). It is a signature crop of the Meinong and Qishan district in Kaohsiung, Taiwan, with over 80% of the country's water snowflake production originating from this region. This aquatic vegetable holds high economic value due to its notable health benefits. However, its planting & cleaning currently depends on labor-intensive manual methods, requiring workers to stand in water for prolonged periods. This process is inefficient, costly, and limits productivity, especially during peak seasons like the lunar new year.

Mechanization is crucial in white water snowflake cultivation. Planting involves hours of bending in muddy, submerged fields, causing physical strain, and relying on foreign labor. Post-harvest cleaning is manual, leading to health risks, excessive costs, and hygiene issues. Machines for planting and cleaning can reduce labor dependency, improve efficiency, ensure product quality, and lower long-term costs, making the industry more sustainable.

Since the mid-20th century, developed nations have relied on costly foreign labor in agriculture due to aging populations, but automated farming offers a viable alternative (Liu et al., 2023). Currently, the stages of planting & cleaning of NH are based on human power. Therefore, present study aims to develop a planting and cleaning machine to reduce labor dependency, enhance cleaning efficiency, and lower operational costs, thereby supporting sustainable, large-scale, pre & post-harvest processing of NH.

## 2. MATERIALS AND METHODS

### 2.1 THE PLANTING TOOL

The white water snowflake planting machine is made of stainless steel, considering the high humidity of the working environment and the high temperatures and sunlight in southern Kaohsiung, as shown in Figure 1. The core component of the planting device is the cutting unit, which is designed to process and meter seedlings efficiently. This unit comprises two counter-rotating screws powered by a DC motor. These screws perform two simultaneous functions: drawing seedling clusters downward and controlling the dispensed quantity based on the motor's runtime, thereby regulating the seedling weight per planting cycle.

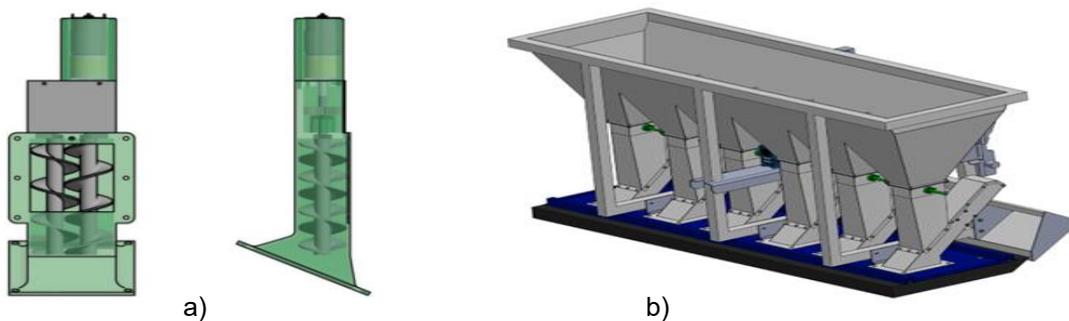


Fig. 1: a) Seedling extruder structure. b) Seedling total machine includes six extruders.

The complete system incorporates six such cutting units arranged in parallel, enabling the simultaneous planting of six positions in a single operation. The entire mechanism is mounted

on a tractor. The system is manually assisted, requiring one operator to steer the vehicle and another to sit at the rear and continuously supply seedlings into the hoppers during operation. This configuration enhances labor efficiency while maintaining uniformity in planting density and seedling distribution.

## 2.2 THE CLEANING MACHINE

Freshly harvested white water snowflakes were collected from Qishan water snowflake farm, Kaohsiung, Taiwan. Before each cleaning cycle, samples were weighed using a precision digital scale. The cleaning water was prepared by dissolving food-grade citric acid (Shandong Ensign Industry Co., Ltd., China) into water tanks (90 × 70 × 38 cm), filled up to 26.5 cm, corresponding to approximately 1,000 L. The required amount of citric acid is precisely measured, mixed for five minutes, and its pH was checked before starting cleaning. Cleaning was conducted using a machine equipped with a conveyor speed adjustable from 25 to 354 mm/s, stabilized for one minute before cleaning. Flat-faced spray nozzles, connected to centrifugal pumps, supplied the cleaning water, with flow rates adjusted by varying the number of active pumps. Water consumption is calculated as  $Q \times T$ , where  $Q$  is the flow rate (L/s) and  $T$  is the cleaning duration (s), measured using a stopwatch.

Cleaning efficiency evaluated through systematic image analysis. Three high-resolution images were captured for each sample before and after cleaning, using an iPhone 16 mounted on a fixed test bench to ensure consistent camera position, angle, and lighting. Images were taken at the root, center, and tip of the sample and analyzed using ImageJ software with manual thresholding in RGB space to differentiate cleaned and uncleaned areas.

## 3. RESULTS & DISCUSSION

### 3.1 THE PLANTING TOOL TEST

The white water snowflake planting tool test was conducted in Qishan water snowflake farm Kaohsiung. Seedlings are ejected stably at 92 to 99% per test. The average time to plant one row of six positions is 2.3 s. Compared to humans, the planting speed has improved considerably. An experiment was conducted to count the number of seedling nodes according to each planting unit. The result is shown in Table 1.

Table 1: Seedling node count and variation across planting units.

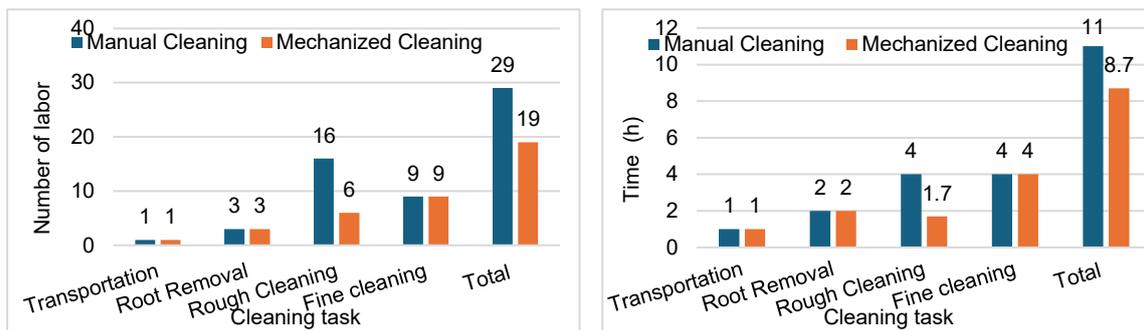
Position	Number of seedling nodes	CV (%)
Unit 1	11	46
Unit 2	10.6	41
Unit 3	12	49
Unit 4	7.7	55
Unit 5	6.1	63
Unit 6	9.4	50

The results indicate that all planting units exceeded the target average of approximately five seedling nodes per position, with values ranging from 6.1 to 12 nodes. Although variability exists among units (CV between 41% and 63%), the device effectively delivers the required minimum seedling density. Importantly, this output can be adjusted to balance planting

objectives with seedling consumption, optimizing both field performance and resource use.

### 3.2 THE CLEANING MACHINE

According to Figure 1(a), mechanized cleaning reduces labor dependency from 29 to 19 labor per ton of water snowflake (a reduction 34.5%). The most substantial decrease is in rough cleaning staff, which goes from 16 to 6 labors. Such a drop makes labor coordination easier and reduces reliance on massive or foreign workforces. Transport, root removal, and fine cleaning time stay the same, as shown in Figure 1(b), but the overall working time also significantly decreases, going from 11 to 8.7 h. (a savings of 20.9%), primarily due to a reduction in rough cleaning time from 4 to 1.7 h. For farmers, mechanized cleaning is a scalable option because of its labor & time efficiency, which also improves throughput and reduces personnel costs.



(a) Number of labor vs cleaning task

(b) Time required vs cleaning task

Fig.1 Manual vs mechanized cleaning for 1 Ton white water snowflake.

### CONCLUSIONS

The mechanical planting and cleaning machine for white water snowflakes improves labor efficiency, planting consistency, and scalability. The cleaning tool cuts time and labor without affecting quality, while the planting tool ensures proper seedling density with adjustable performance. Together, these technologies support sustainable NH production, enabling commercial growth and reducing reliance on manual labor.

### ACKNOWLEDGEMENTS

This study was supported by a research grant from the projects: 112AS-1.6.5-ST-a1, 113 農再-2.4.1-1.1-糧-014(21), 114 農再-2.3.1-1.1-糧-001(21) Ministry of Agriculture, Taiwan.

### REFERENCES

- Abelti, A. L., T. A. Teka, and G. Bultosa. 2023. Review on edible water lilies and lotus: Future food, nutrition, and their health benefits. *Applied Food Research*. 3(1): 100264.
- Ko, H. J., S. H. Huang, and L. T. Ng. 2014. Chemical compositions and antioxidant activities of a specialty aquatic vegetable *Nymphoides hydrophylla* in Taiwan. *J. Aquatic Food Product Technol.* 23(6): 555–566.
- Liu, J., Y. Fang, G. Wang, B. Liu, and R. Wang. 2021. The aging of farmers and its challenges for labor-intensive agriculture in China: A perspective on farmland transfer plans for farmers' retirement. *J. Rural Stud.* 84: 86–96.