# DEVELOPMENT OF PRECISION PLANTER AND FERTILIZER APPLICATOR FOR ONION (*Allium Cepa L.)*

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**ABSTRACT**

This study focuses on the design, development, and performance evaluation of a precision planter and fertilizer applicator for onion (Allium cepa L.) cultivation in the Philippines. The machine was designed to enhance planting efficiency, optimize fertilizer application, and reduce labor costs, thereby addressing key challenges faced by small-scale farmers, such as labor shortages and inefficient resource utilization. Powered by a gasoline-driven walk-behind tractor, the system integrates a chain conveyor for planting pre-germinated bulbs and a metering device for precise fertilizer delivery. Field trials were conducted on a 1,200 m² area in the City of Ilagan, Isabela, using a two-factor factorial experiment in a randomized complete block design (RCBD). The study assessed single- and double-pass soil cultivation under three operating speeds: 0–1.0 m/s, 1.01–1.5 m/s, and 1.51–2.0 m/s. Results revealed that the machine achieved a maximum field efficiency of 95.98% at a speed of 1.51–2.0 m/s, with a mean field capacity of 0.087 ha/h. Compared to manual planting, labor costs were reduced by 86.03%, while onion output capacity increased from 42.78 kg/hr to 81.30 kg/hr. Similarly, fertilizer application improved, rising from 37.41 kg/hr to 82.97 kg/hr, with the lowest missing-hill rate of 4.76% observed at 1.01–1.5 m/s. Economic analysis indicated a benefit-cost ratio of 7.89, a payback period of 46 days, and a return on investment (ROI) of 788.95%. The results demonstrate that the developed machine operates efficiently under varying soil conditions and speeds, significantly reducing labor dependency, minimizing fertilizer waste, and improving productivity. Overall, the innovation supports sustainable and cost-effective onion farming, offering small-scale farmers a practical solution to improve operational efficiency and profitability.

*Keywords: Precision agriculture, onion cultivation, field efficiency, economic viability, Philippines*

## INTRODUCTION

Onion (Allium cepa L.) is a valuable crop in the Philippines, playing a crucial role in culinary traditions and economic livelihoods. Approximately 78% of onion production is used in food preparation (Lopez & Anit, 1994). The country is experiencing a growing demand for onions, with per capita consumption estimated at 13.67 pounds (De Guzman, 2023). However, onion cultivation is labor-intensive, requiring 194.25 man-hours per hectare for manual planting. Labor costs account for 38% of total production expenses (Vijay et al., 2017; PSA, 2019). Traditional planting methods can be inefficient, leading to uneven spacing, inconsistent seed depth, and seed wastage, all of which reduce crop yields and increase costs. Additionally, rising labor costs and recent shortages of onions, driven by inflation and agricultural damage due to climate change (Yang, 2023), highlight the urgent need for mechanized solutions to enhance productivity and affordability. Onion cultivation spans 22 provinces in the Philippines, with Cagayan Valley contributing 6% of the national production (DA-AMAD, 2019; PSA, 2021). The average landholding per farmer is 1.29 hectares (PSA, 2015), indicating the potential for household-scale machinery to reduce the burden of manual labor and improve efficiency. Mechanization levels in the Philippines are relatively low compared to other Asian countries, with mechanical power providing only 35% of total farm power in 1990, while human labor accounted for 50% (PCARRD, 2002). This reliance on manual labor worsens challenges in onion production, particularly in labor-intensive tasks such as planting and fertilizer application.

Fertilizer application also presents challenges, as traditional broadcast methods can lead to nutrient losses through leaching, denitrification, or volatilization, which reduce nutrient efficiency and may damage seedlings (Braganza, 2024). Precision agriculture offers solutions by optimizing resource use and minimizing labor demands (Liaghat & Balasundram, 2010). This study addresses these challenges by developing a precision planter and fertilizer applicator specifically designed for onion cultivation for small-scale farmers. The machine aims to reduce labor costs by 40%, improve planting accuracy and capacity per hectare, and minimize fertilizer waste through controlled and regulated application, contributing to sustainable onion production and strengthening food security in the Philippines.

## OBJECTIVE OF THE STUDY

The Study on the Development of a Precision Planter and Fertilizer Applicator for onions aims to

1. To design and fabricate an efficient Onion Bulb Precision Planter and Fertilizer Applicator;
2. To conduct a technical performance evaluation of the machine,
3. To determine the economic viability of the Precision Planter and Fertilizer Applicator for onions.

## MATERIALS AND METHODS

### Performance Test Material

Materials included: camera, pre-germinated "Red Pinoy" onion bulbs, ammonium phosphate fertilizer, digital weighing scale, data sheet, tachometer, plastic bag, stopwatch, pencil, tape measure, string, core sampler, and caliper.

### Testing and Evaluation

*Description of the Machine*

An Onion Planter cum Fertilizer Applicator implement uses a Gasoline walk-behind agricultural tractor that serves as the power source of the machine. The ground wheel transmits power through a chain system, which allows the bulb conveyor and the fertilizer applicator to rotate and deliver the output product. The Fertilizer applicator uses fabricated punched rubber as a metering device to drop fertilizer into the soil. A feeder hopper is located per the system of an onion planter and fertilizer applicator, and it serves as the entry point for the materials. A mini bucket conveyor is attached to the chain to deliver the onion bulb into the soil. A furrow opener and furrow closer are attached to the plant, and fertilizer is properly covered to control the planting depth of the plant.

*Principle of Operation*

The primary purpose of the onion planter and fertilizer applicator is to efficiently deliver pre-germinated onion bulbs and prilled fertilizer directly into the soil, significantly reducing the time and labor required compared to traditional manual methods. The system is designed with separate hoppers that independently feed the pre-germinated bulbs and fertilizer, ensuring precise placement and improved planting accuracy. For the onion planter, a mini bucket conveyor is attached to the chain to scope the onion bulb with a spacing of 17cm, convey it upward, and drop it into the soil. For the fertilizer applicator, a rotating rubber roll is punched with 6 holes placed tangentially to the direction of rotation, with a 1.5 cm diameter. Once filled with fertilizer, a flat stainless steel plate scrapes and directly drops into the soil.

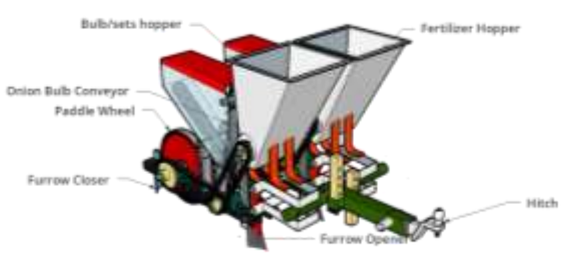


*Figure 1. Perspective Diagram of Onion Planter cum Fertilizer Applicator*

*Gathering of Sample Materials*

Forty (40) kg of pre-germinated onion bulbs with a variety of “Red Pinoy” were purchased for 80 pesos per kilogram. Two (2) kg of onion bulbs were used in each treatment. 36 kg of prilled Ammonium Phosphate (21-0-0) fertilizer was used for the 18 sample treatments, with 2kg each.

*Data Gathering*

Data collected: bulb weight, polar/equatorial diameters, fertilizer weight, bulbs after dropping, fertilizer after discharge, operation time, fuel consumption, test area, and processing time.

*Test Scenario and Field Trial*

The implement's fabrication and development were done at the Ka Tribu Machine shop at Echague, Isabela, and were tested at the DA-CVRC Field Trial. The field was measured into a 1200 square meter area, subdivided into 2 sets of soil cultivation, 3 sets of speeds, and replicated three (3) times accordingly. The experimental layout was organized as follows:

**Experimental Layout and Design**

*Factor A:*

A1-Single Passed Soil Cultivation (Bulk Density: *1.357 g/cc)*

A2-Double Passed Soil Cultivation (Bulk Density: *1.423 g/cc)*

*Factor B:*

B1-Speed- 0 to 1.0 meters per second (0 to 3.6 km/hr)

B2-Speed - 1.01 to 1.5 meters per second (3.61 to 5.4 km/hr)

B3-Speed - 1.51 to 2.0 meters per second (5.41 to 7.2 km/hr

**Table 1**
*Experimental Layout for Precision Planter and Fertilizer Applicator*

| Replication 1 | Replication 2 | Replication 3 |
|---|---|---|
| A1B1 | A1B2 | A1B3 |
| A2B1 | A1B1 | A1B2 |
| A2B2 | A2B1 | A1B1 |
| A1B2 | A2B2 | A2B3 |
| A1B3 | A2B3 | A2B2 |
| A2B3 | A1B3 | A2B1 |

*Note: Total Experimental Area: 1200 square meters (0.12 ha)*
*Area per Treatment-56 square meters (0.0056 ha)*

*Experimental Design*

Two-factor factorial using Statistical Tool for Agricultural Research (STAR).

*Statistical Analysis*

The analysis was summarized in an Analysis of Variance (ANOVA) table to measure the significance and insignificance of the machines.

**Machine Formulas and Computations**

The collection of data is essential in both the field and the machinery testing center. This data was used to analyze and evaluate various aspects of the equipment's performance and functionality.

*Discharge Measurement.* Both the onion and the fertilizer were weighed in equal amounts of 5 kg each. The measurements were taken 5 minutes after the operation commenced.

*Speed of operation and turning time.* During the planter's field trial, the operation's speed was measured by recording the time required to cover a 10 m distance using a watch.

*Speed (Km/h)* = Distance covered (m)Time required to cover the distance (Sec) X 3.6……………….……… eq. (1)

*Missing hill percentage:* The miss index is the ratio of the number of spacing greater than 1.5 times of set spacing and the total number of measured spacings

M= (nt-na)/nt x100 ……………...…eq. (2)

Where: M= missing hills, %

Nt - Number of hills present in a row for a given row length, theoretically

na - Actual number of hills observed in a row for the same length

*Effective Field Capacity***.** Area covered by the onion planter and fertilizer applicator per hour, conducted in the machine testing area

AFC=Ao/T …………………..……eq. (3)

Where: AFC- Actual Field Capacity, ha/ hr
Ao- Area of plot, ha
T-Time taken, hr

*Theoretical Field Capacity***-** is the amount of Onion and Fertilizer discharged per unit of time conducted at the machinery center

TFC = (WxS)/10 ……………………eq. (4)

Where: TFC- Theoretical Field Capacity, ha/hr

W - Width of Planter/Fertilizer Applicator, m

S - Speed of Operation, km/hr

*Field Efficiency* **is** the ratio of Actual Field Capacity and Theoretical Field Capacity, measured in percentage.

FE=AFC/TFC X 100………………eq.( 5)

Where: FE-Field Efficiency, %

AFC-Actual Field Capacity, ha/ hr

TFC- Theoretical Field Capacity, ha/hr

**Machine Cost Analysis**

Cost and return analysis using the actual data gathered during the experiment for the Design and Development of the Onion Bulb Planter and Fertilizer Applicator includes the cost of all materials used in the setup. The following Formulas were used:

*Fixed Cost:* It is the sum of depreciation and interest on investment.

FC= D + IOI ……………..……………eq. (6)

Where: FC – fixed cost, PHP/yr
D – Depreciation, PhP/yr
IOI – interest on investment, PhP/y

*Depreciation* is the reduction of the recorded cost of a fixed asset.

D = (IC-SV)/n …………………………....eq. (7)

Where: D – Depreciation, PhP/year
SV – Salvage value, PhP
IC – Investment cost, PHP/year
n – Lifespan, years

*Interest on Investment:* It is the charge for the use of the money invested in the structure.

IOI =(IC+SV)/2 × i/100 ………………...eq. (8)

Where: IOI - Interest on investment, PHP/year

IC – Investment cost, PHP
SV- Salvage value, PHP

i- Interest rate, %

*Variable Cost* The variable cost area is the cost that changes due to the variation in the volume of the activity. It is computed by adding the repair and maintenance value, input cost, and labor cost.

VC = RM + LC + MC ……………………..eq. (9)

Where: VC- variable cost, PHP/year

RM- repair and maintenance, PHP/year
LC- labor cost, PhP /year
MC- PhP /year

*Total Cost:* The total cost refers to all the expenses incurred to reach the level of output. This is computed by adding the fixed cost and the variable cost.

TC = FC + VC …………...……………eq. (10)

Where: TC- total cost, PhP /year

FC- fixed cost, PhP /year
VC- variable cost, PhP /year

*Production Cost:* The total cost per year is divided by the capacity per year.

PC = TC/C……………………..eq. (11)

Where: PC – Production cost, PhP /kg

TC – Total cost, PhP /year

C – Capacity, kg /year

*Annual Net Income:* It is the difference between the revenue and production cost, given by the formula:

ANI = R – PC ……………………..……eq. (12)

Where: ANI – Net income, PhP /year

R – Revenue, PhP /year
PC – Production cost, PhP/year

*Break-Even Point:* It is a method for determining the project's viability. The unit price was computed by dividing the total variable cost by the total weight of onions per year.

BEP = TFC/(CR-(VC/C)) ……………..eq. (13)

Where: BEP – break-even point, kg

TFC – total fixed cost, PhP/year
CR – cost of the system per kg, PhP
VC – variable cost, PHP/hour
C – Capacity of the system, kg/hour

*Payback Period.* It focuses on the length of time it will take for the investment to return its original cost or the number of years required for cash inflows to just equal cash outflows. The payback period is often called a simple payout method, indicating the project's liquidity rather than profitability.

PP = IC/ANI……………………………....eq. (14)

Where: PP – payback period, year

IC – investment cost, PhP
ANI – annual net income, PhP/year

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**RESULT AND DISCUSSION**

**1. Field Efficiency**

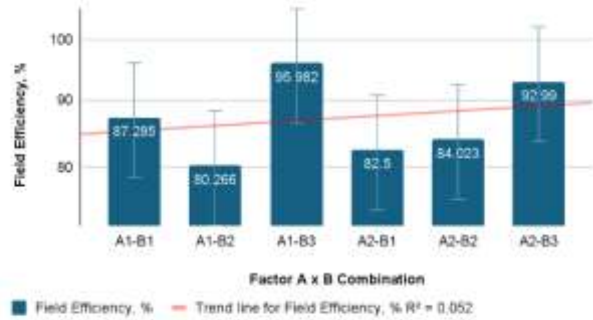


Figure 1. *Planting and fertilizer application efficiency of the machine operated at different speeds, %*

The onion planter and fertilizer applicator achieved a peak field efficiency of 95.982% at 1.51–2.0 m/s (Table 1, Figure 2), with a mean of 86.44% and a CV of 6.25%. Factor B (speed) significantly affected efficiency (p=0.0477, F=4.33, Table 2), with B3 (91.44%) outperforming B1 (84.39%) and B2 (82.59%) (LSD=6.91%).

**Table 1**
*Field Efficiency of the Onion Planter and Fertilizer Applicator at Two Different Factors (%)*

| Replication | Factor A | Factor B | | | Total | Mean |
|---|---|---|---|---|---|---|
| | | B1 | B2 | B3 | | |
| 1 | A1 | 87.285 | 80.266 | 95.982 | 263.533 | 87.844 |
| 1 | A2 | 82.50 | 84.02 | 94.99 | 266.51 | 88.83 |
| 2 | A1 | 94.99 | 89.271 | 85.784 | 270.045 | 90.01 |
| 2 | A2 | 88.97 | 91.22 | 89.02 | 269.21 | 89.73 |
| 3 | A1 | 77.545 | 72.766 | 90.897 | 241.208 | 80.40 |
| 3 | A2 | 75.07 | 78.01 | 92.01 | 245.09 | 81.696 |
| Total | | 506.36 | 495.553 | 553.683 | 1555.59 | |
| Mean | | 84.39[ab] | 82.59[b] | 91.44[a] | | 86.442 |

Factor A was non-significant (p = 0.9666), indicating consistent performance across capacity types. Replication effects were significant (p=0.0463), with Replication 2 showing the highest efficiencies. This high efficiency aligns with

Liaghat and Balasundram (2010) on precision agriculture's ability to optimize resource use, surpassing manual planting's labor-intensive 194.25 man-hours/ha (Vijay et al., 2017. The chain conveyor's 17 cm spacing ensures precise bulb placement, but minor wheel slippage at higher speeds suggests potential for further optimization, as noted by Smith et al. (2018).

**Table 2**

*ANOVA for Field Efficiency*

| Source of Variation | Degrees of Variation | Sum of Squares | Mean of Squares | F-Computed | P-Value |
|---|---|---|---|---|---|
| Replication | 2 | 245.17 | 122.5866 | 4.24 | $0.0463^{*}$ |
| Factor A | 1 | 0.0534 | 0.0534 | 0.00 | $0.9666^{ns}$ |
| Factor B | 2 | 242.0464 | 121.0232 | 4.19 | $0.0477^{*}$ |
| Factor A x B | 2 | 49.6441 | 24.8220 | 0.86 | $0.4526^{ns}$ |
| Error | 10 | 288.9314 | 28.8931 | | |
| Total | 17 | 825.8484 | | | |

CV=6.25 %, LSD (Factor B) = 6.91 %, *- Significant, ns-not significant

## 2. Field Capacity

Field capacity increased significantly with speed (p=0.0000, F=264.27, Table 4), from 0.056 ha/hr at B1 to 0.116 ha/hr at B3, with a mean of 0.087 ha/hr (Table 3; LSD=0.0058 ha/hr). Factor A was significant (p=0.0002, F=33.72), with A1 (0.091 ha/hr) outperforming A2 (0.081 ha/hr) (LSD=0.0047 ha/hr). Replication effects were non-significant (p=0.3879), indicating consistent performance. The low CV (5.27%) reflects reliable results. This capacity exceeds manual planting (0.05 ha/man/day, Rathore et al., 2021) and is competitive with tractor-operated planters (0.15 ha/hr, Rathinakumari & Jesudas, 2015), supporting the study's objective of enhancing productivity for small-scale farmers. The results align with Smith et al. (2018) on optimized operational parameters improving field coverage.

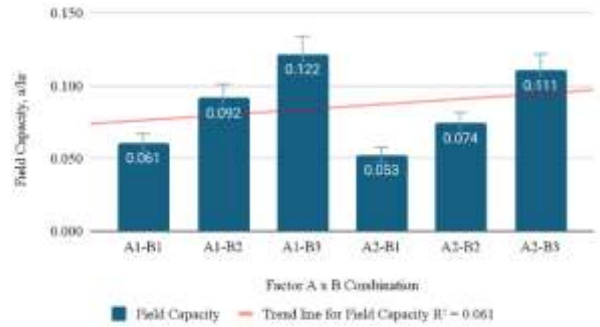


Figure 2. *Field capacity of the onion planter and fertilizer applicator operated at different speeds, ha/hr*

***Table 3***

*The average field capacity of the onion planter and fertilizer applicator operated at different speeds, ha/hr*

| Replication | Factor A | Factor B | | | Total | Mean |
|---|---|---|---|---|---|---|
| | | B1 | B2 | B3 | | |
| 1 | A1 | 0.061 | 0.092 | 0.122 | 0.275 | 0.091 |
| 1 | A2 | 0.053 | 0.074 | 0.117 | 0.244 | 0.081 |
| 2 | A1 | 0.061 | 0.092 | 0.122 | 0.275 | 0.091 |
| 2 | A2 | 0.058 | 0.082 | 0.105 | 0.245 | 0.081 |
| 3 | A1 | 0.061 | 0.092 | 0.122 | 0.275 | 0.091 |
| 3 | A2 | 0.047 | 0.067 | 0.111 | 0.225 | 0.075 |
| Total | | 0.341 | 0.499 | 0.699 | | |
| Mean | | $0.056^{c}$ | $0.083^{b}$ | $0.116^{a}$ | | 0.087 |

**Table 4**

*Analysis of Variance of Field Capacity*

| Source of Variation | Degrees of Variation | Sum of Squares | Mean of Squares | F-Computed | P-Value |
|---|---|---|---|---|---|
| Replication | 2 | 0.0000 | 0.0000 | 1.04 | $0.3879^{ns}$ |
| Factor A | 1 | 0.0007 | 0.0007 | 33.72 | $0.0002^{**}$ |
| Factor B | 2 | 0.0107 | 0.0054 | 264.27 | $0.0000^{**}$ |
| Factor A x B | 2 | 0.0001 | 0.0000 | 1.71 | $0.2301^{ns}$ |
| Error | 10 | 0.0002 | 0.0000 | | |
| **Total** | **17** | **0.0117** | | | |

CV= 5.27 %, LSD (Factor A) = 0.0047 ha/hr. LSD (Factor B) = 0.0058 ha/hr *- Significant, **- Highly Significant, ns-not significant

## 3. Onion Planter Output Capacity

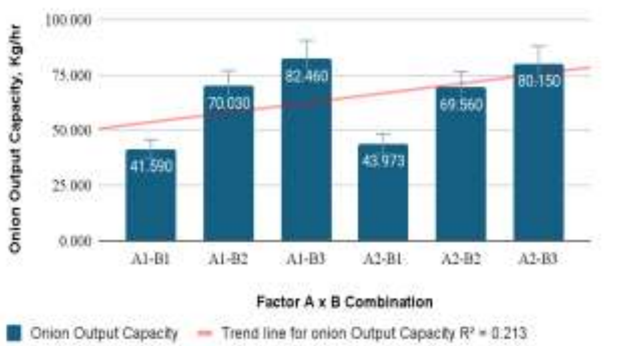


*Figure 3. The average output capacity of onion planters operated at different speeds. kg/hr*

**Table 5**

*The average output capacity of onion planters operated at different speeds. kg/hr*

| Replication | Factor A | Factor B | | | Total | Mean |
|---|---|---|---|---|---|---|
| | | B1 | B2 | B3 | | |
| 1 | A1 | 44.62 | 66.4 | 82.33 | 193.35 | 64.45 |
| 1 | A2 | 46.12 | 71.58 | 80.15 | 197.85 | 65.95 |
| 2 | A1 | 48.22 | 79.83 | 79.90 | 207.95 | 69.31 |
| 2 | A2 | 50.02 | 76.12 | 79.18 | 205.32 | 68.44 |
| 3 | A1 | 31.93 | 63.86 | 85.15 | 180.94 | 60.31 |
| 3 | A2 | 35.78 | 60.98 | 81.12 | 177.88 | 59.29 |
| Total | | 256.69 | 418.77 | 487.83 | | |
| Mean | | 42.78$^{c}$ | 69.79$^{b}$ | 81.30$^{a}$ | | 64.63 |

**Table 6**

*Analysis of Variance of Onion Planter Output Capacity*

| *Source of Variation* | *Degrees of Variation* | *Sum of Squares* | *Mean of Squares* | *F-Computed* | *P-Value* |
|---|---|---|---|---|---|
| Replication | 2 | 250.01 | 125.00 | 4.33 | 0.0441$^{*}$ |
| Factor A | 1 | 0.0787 | 0.0787 | 0.00 | 0.9594$^{ns}$ |
| Factor B | 2 | 4692.49 | 2346.24 | 81.34 | 0.0000$^{**}$ |
| Factor A x B | 2 | 16.7772 | 8.3886 | 0.29 | 0.7538$^{ns}$ |
| Error | 10 | 288.4395 | 28.8440 | | |
| Total | 17 | 5247.8100 | | | |

CV= 8.31 %, LSD (Factor B) = 6.91 kg/hr *- Significant, **- Highly Significant, ns-not significant

The results are summarized in Table 5 and analyzed in Table 6 (ANOVA). The ANOVA revealed a significant effect of Factor B (p = 0.0000, F = 81.34), with output capacity increasing from 42.78 kg/hr at B1 to 81.30 kg/hr at B3, with an LSD of 6.91 kg/hr. Factor A showed no significant difference (p = 0.9594). Replication effects were significant (p = 0.0441, F = 4.33), with Replication 2 yielding the highest outputs and Replication 3 the lowest. The interaction between Factors A and B was not significant (p = 0.7538). The overall mean output capacity was 64.63 kg/hr, indicating strong performance. Higher speeds improved output, supporting findings by Smith et al. (2018). The machine's output surpasses manual planting rates (0.05 ha/man/day; Rathore et al., 2021) and is competitive with tractor-operated planters (Rathinakumari & Jesudas, 2015). The chain conveyor's 17 cm spacing ensures uniform bulb distribution, as noted by Ovtov et al. (2022). However, variability at B3 may lead to bulb skips, aligning with challenges discussed by Zheng et al. (2021). Significant replication effects may relate to soil moisture variations, as observed by Shalaby et al. (2018).

## 4. Fertilizer Applicator Output Capacity

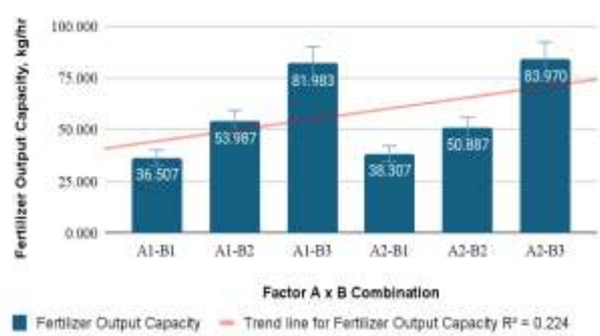


*Figure 4. The average output capacity of the Fertilizer Applicator operated at different speeds. kg/hr*

**Table 7**

*The average output capacity of a fertilizer applicator operated at different speeds. kg/hr*

| Replication | Factor A | Factor B | | | Total | Mean |
|---|---|---|---|---|---|---|
| | | B1 | B2 | B3 | | |
| 1 | A1 | 53.22 | 53.22 | 53.22 | 176.78 | 58.92 |
| 1 | A2 | 53.22 | 53.22 | 53.22 | 175.73 | 58.57 |
| 2 | A1 | 53.22 | 53.22 | 53.22 | 179.67 | 59.89 |
| 2 | A2 | 53.22 | 53.22 | 53.22 | 181.5 | 60.5 |
| 3 | A1 | 53.22 | 53.22 | 53.22 | 160.98 | 53.66 |
| 3 | A2 | 53.22 | 53.22 | 53.22 | 162.26 | 54.08 |
| Total | | 53.22 | 53.22 | 53.22 | | |
| Mean | | 37.41c | 52.44b | 82.97a | | 57.60 |

**Table 8**

*Analysis of Variance of Fertilizer Applicator Output Capacity*

| Source of Variation | Degrees of Variation | Sum of Squares | Mean of Squares | F-Computed | P-Value |
|---|---|---|---|---|---|
| Replication | 2 | 131.6896 | 65.8448 | 4.17 | 0.0483* |
| Factor A | 1 | 0.2358 | 0.2358 | 0.01 | 0.9052ns |
| Factor B | 2 | 6470.43487 | 3235.2174 | 204.69 | 0.0000** |
| Factor A x B | 2 | 24.9595 | 12.4798 | 0.79 | 0.4804ns |
| Error | 10 | 158.0537 | 15.8054 | | |
| Total | 17 | 56785.3734 | | | |

*CV= 6.90 %, LSD (Factor B) = 5.11 kg/hr *- Significant, **- Highly Significant, ns-not significant*

The fertilizer applicator's output capacity was evaluated in a 1200-square-meter area in San Felipe, Isabela, focusing on two factors: A) effective and theoretical capacity, and B) speeds of 0–1.0 m/s, 1.01–1.5 m/s, and 1.51–2.0 m/s. Results showed that Factor B significantly affected output (p=0.0000, F=204.69), increasing from 37.41 kg/hr at B1 to 82.97 kg/hr at B3, with a least significant difference of 5.11 kg/hr. Factor A had no significant impact (p=0.9052, F=0.01), and replication effects were significant (p=0.0483). The overall mean output was 57.60 kg/hr, indicating efficient performance. The punched rubber metering device ensures precise fertilizer placement, reducing losses compared to manual methods (Braganza, 2024). This supports Singh et al. (2018) on mechanized application improving uniformity and aligns with the study's aim to minimize fertilizer waste.

## 5. Soil Conditions and Bulb Properties

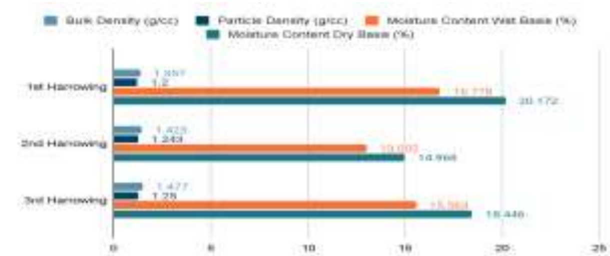


*Figure 5. Soil conditions for the field testing of onion planters operated at different speeds.*

**Table 9**

*Soil conditions for the field testing of onion planters operated at different Cultivation stages*

| Cultivation Stages | Bulk Density (g/cc) | Particle Density (g/cc) | Moisture Content Wet Basis (%) | Moisture Content Dry Basis (%) |
|---|---|---|---|---|
| First Harrowing | 1.357 | 1.200 | 16.778a | 20.172a |
| Second Harrowing | 1.423 | 1.243 | 13.002b | 14.968b |
| Third Harrowing | 1.477 | 1.250 | 15.563a | 18.446a |
| Mean | 1.42 | 1.23 | 15.11 | 17.86 |
| ANOVA Result | ns | ns | ** | ** |
| CV, % | 6.5 | 4.37 | 6.38 | 7.38 |
| LSD | - | - | 2.18 | 2.98 |

***-highly significant, ns-not significant*

**Table 10**

*Physical and Geometric Properties of an onion operated at different replications.*

| Replication | Polar Diameter (cm) | Equatorial Diameter (cm) | Shape Index | Weight (g) |
|---|---|---|---|---|
| *1* | *3.726* | *2.478* | *0.671* | *11.494* |
| *2* | *3.240* | *2.022* | *0.628* | *8.300* |
| *3* | *2.897* | *1.815* | *0.631* | *6.817* |
| *Mean* | *3.29* | *2.10* | *0.64* | *8.87* |
| *ANOVA Result* | *ns* | *ns* | *ns* | *ns* |
| *CV, %* | *10.96* | *11.53* | *7.31* | *20.3* |

*ns-not significant*

The machine demonstrated consistent performance across varying soil conditions (Table 9), with a notable influence of moisture content on a wet basis (CV = 6.38%), highlighting its adaptability across different soil preparation stages, including first harrowing, second harrowing, and final leveling. This versatility offers a significant advantage for farmers in Isabela, where soil types and preparation practices often vary. These findings align with the observations of Zheng et al. (2021), who emphasized the need for robust machine designs capable of operating effectively under diverse soil conditions. Furthermore, the furrow opener and closer efficiently managed soil interactions, maintaining optimal planting depth and ensuring precise fertilizer placement. This mechanism minimizes nutrient losses compared to conventional broadcast application methods, supporting Braganza's (2024) findings on improved fertilizer utilization and enhanced planting efficiency.

Similarly, the non-significant variation in "Red Pinoy" bulb properties (polar and equatorial diameter, weight, Table 10) across speeds indicates that the chain conveyor and mini bucket system can handle diverse bulb characteristics without compromising planting accuracy. This addresses a research gap in understanding onion bulb properties for mechanized planting (Shalaby et al., 2018) and supports the study's objective of developing a crop-specific machine. The machine's ability to maintain performance across bulb sizes and shapes is particularly valuable for farmers using locally sourced bulbs, which may vary in germination stage or size, enhancing its applicability in real-world farming scenarios.

## 6. Percentage of Missing Hills

The percentage of missing hills was lowest at B2 (1.01–1.5 m/s) at 4.76% (Table 11), with a grand mean of 4.891% (CV=12.93%). Factor B significantly affected missing hills (p=0.0000, F=220.289), increasing from 0.000% (A1) and 2.7367% (A2) at B1 to 9.5200% (A1) and 8.4233% (A2) at B3 (LSD=1.15%). The A-B interaction was significant (p=0.0006), but Factor A (p=0.4095) and replication (p=0.4062) were non-significant. Optimal performance at B2 aligns with Ovtov et al. (2022) on uniform bulb distribution. Higher misses at B3 suggest bulb skips (Zheng et al., 2021), while B1's precision reflects effective metering (Helmy et al., 2005). The machine's performance is comparable to manual planters (2.22%, Rathore et al., 2021), addressing onion-specific mechanization (Karam & Ghandour, 2015.

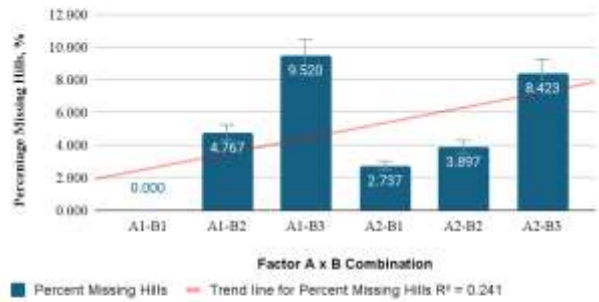


***Figure 6.** Percentage Missing Hills of onion planters operated at different speeds, %*

**Table 11**

*Percentage of missing hills in an onion planter operated at different speeds. kg/hr*

| Replication | Factor A | Factor B | | | Total | Mean |
|---|---|---|---|---|---|---|
| | | B1 | B2 | B3 | | |
| 1 | A1 | 0 | 4.73 | 9.24 | 13.97 | 4.657 |
| 1 | A2 | 2.33 | 3.2 | 8.56 | 14.09 | 4.697 |
| 2 | A1 | 0 | 4.77 | 10.22 | 14.99 | 4.997 |
| 2 | A2 | 2.22 | 3.25 | 8.46 | 13.93 | 4.643 |
| 3 | A1 | 0 | 4.8 | 9.1 | 13.9 | 4.633 |
| 3 | A2 | 3.66 | 5.24 | 8.25 | 17.15 | 5.717 |
| Total | | 8.21 | 25.99 | 53.83 | | |
| Grand Mean | | | | | | 4.891 |
| Mean | A1 | 0.000$^{c}$ | 4.7667$^{b}$ | 9.5200$^{a}$ | | |
| | A2 | 2.7367$^{c}$ | 3.8967$^{b}$ | 8.4233$^{a}$ | | |

**Table 12**
*Analysis of Variance of Percentage Missing Hills*

| Source of Variation | Degrees of Variation | Sum of Squares | Mean of Squares | F-Computed | P-Value |
|---|---|---|---|---|---|
| Replication | 2 | 0.7898 | 0.3949 | 0.99 | 0.4062$^{ns}$ |
| Factor A | 1 | 0.2965 | 0.2965 | 0.74 | 0.4095$^{ns}$ |
| Factor B | 2 | 176.2432 | 88.1216 | 220.289 | 0.0000$^{**}$ |
| Factor A x B | 2 | 13.8769 | 6.9385 | 17.34 | 0.0006$^{**}$ |
| Error | 10 | 4.0005 | 0.4000 | | |
| Total | 17 | 195.2069 | | | |

*CV= 12.93 %,  LSD (Factor B) = 1.15 %,  LSD (Factor A x B) = 1.15%*
**- Significant, **- Highly Significant, ns-not significant*

## 7. Economic Analysis

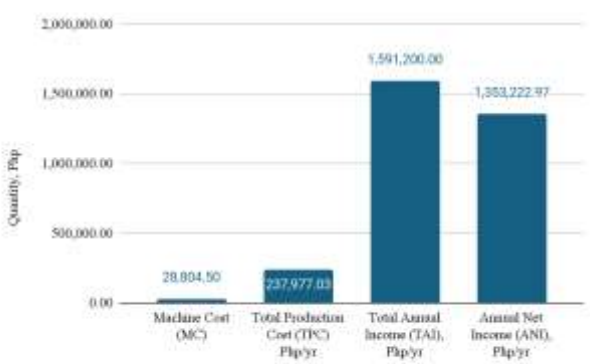


*Figure 7. Cost and Return analysis of onion planters operated at different speeds, %*

***Table 13***
*Economic Analysis of Planter and Fertilizer Applicator for Onion*

| Particulars | Quantity |
|---|---|
| Machine Cost (MC) | 28,804.50 |
| Total Production Cost (TPC) Php/yr | 237,977.03 |
| Total Annual Income (TAI), Php/yr | 1,591200 |
| Annual Net Income (ANI), Php/yr | 1,353,222.97 |
| Benefit Cost Ratio (BCR) | 5.69 |
| Break-Even Point (OBEP), kg/yr | 41.52 |
| Return on investment (ROI), % | 568.64 |
| Payback Period (PBP), yrs | 0.1759 |

The economic analysis (Table 13) reveals a total operating cost of Php 237,977.03/yr, an annual net income of Php 1,353,222.97/yr, a benefit-cost ratio of 5.69, a payback period of 64 days, and a return on investment of 568.64%. These metrics confirm the machine's high economic viability, particularly for small-scale farmers facing labor costs of Php 6,172.09/ha for manual planting (Rathore et al., 2021). The 86.03% (Onion Planter: Php.. 862.06/ha) labor cost reduction directly addresses the challenge of high labor expenses and supports the study's objective of determining economic viability. The low break-even points (41.52 kg/yr) indicate that the machine is cost-effective even for small production volumes, making it accessible to farmers with average landholdings of 1.29 ha (PSA, 2015).

The rapid payback period and high benefit-cost ratio align with the findings of Tey and Brindal (2012), who emphasized the importance of economic feasibility for the adoption of precision agriculture. This study shows an 86.03% reduction in costs, which is more favorable compared to the 30% cost savings achieved with a tractor-operated onion set planter (Rathinakumari & Jesudas, 2015). The machine's profitability makes it an appealing investment, supporting the recommendation for policy subsidies to promote its adoption.

## CONCLUSION

The onion precision planter and fertilizer applicator significantly improve planting efficiency and reduce labor costs by 86.03% compared to manual methods. Its high field efficiency (95.982%), robust field capacity (0.087 ha/hr), and precise application at optimal speeds (1.01–1.5 m/s for planting, 1.51–2.0 m/s for fertilizer) make it ideal for onion cultivation. The machine's economic viability, with low operating costs and high returns, supports its adoption by small-scale farmers, addressing labor shortages and fertilizer waste while promoting sustainable onion production in the Philippines.

## RECOMMENDATIONS

Based on the study's findings, the following recommendations are proposed:

1. *Adoption by Farmers:* Promote the machine's use among small-scale onion farmers in Isabela to reduce labor costs and enhance efficiency.
2. *Speed Optimization*: Operate at 1.01–1.5 m/s for planting to minimize missing hills and 1.51–2.0 m/s for fertilizer application to maximize output.
3. *Further Research:* Test the machine with other onion varieties and other crops like potato and garlic in larger fields to validate versatility.

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