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# Development of a Metering Device for a Garlic Planter

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## ABSTRACT

*Planting has the highest input cost in garlic production and is done manually. A metering device was designed and built for a two-wheel, push-type garlic planter. The metering mechanism consists of gathering cups attached to a moving chain, which is driven by a pair of 16-tooth sprockets. These sprockets are in turn driven by a spiked rear wheel. The average planting distance was 21.25 cm. An optimal picker speed was found to be 0.037 m/s. Tests revealed that the singulation efficiency achieved was 69.65%, close to the predicted value of 71.27%. However, there was a relatively high missed hill percentage of 19.9%, in contrast to the predicted value of 5.88%. This was attributed to garlic cloves bouncing out of the gathering cup due to vibration, leading to a significant difference in missed hill percentages between the actual and predicted values. It is recommended to improve the design of the gathering cup in releasing the cloves to address this issue.*

**Keywords:** *garlic planter, metering device, singulation*

# INTRODUCTION

Garlic (*Allium sativum* L.) is a valuable crop. Its cloves are utilized in both medicine and culinary. This crop is in high demand in both domestic and foreign markets. Garlic farming in the country primarily relies on manual operations. Manual farming is expensive and labor-intensive, which causes farmers to face some issues and problems. This normally leads to the importation of garlic. In 2016, the country imported 94% of its garlic (PSA, 2019). During the dialogue between Ilocos garlic growers and the Department of Agrarian Reform (DAR) Region 1 in 2017, the country's production decreased. Plant diseases, lack of quality seedlings, and lack of new production technology were the causes of the decline. To revive the garlic industry, DAR identified various forms of support including but not limited to inputs, production and postharvest technologies, support infrastructure, and assured market support.

In garlic production, machinery is only used for transportation, irrigation, and soil preparation; a sprayer is used for applying pesticides and weedicides. Basal or fertilizer application, clove separation, planting, mulching, weeding, harvesting, cleaning, sorting, bundling, and drying are all done manually. The most expensive operation in garlic production is planting. According to the Department of Agriculture – Ilocos Norte Research and Experiment Center, planting alone requires 60 man-days per hectare.

Garlic cloves are directly seeded either on a prepared raised bed or flatbed. Raised beds facilitate higher crop yield and productivity. The raised bed planting technique improves garlic productivity. Farmers use the flatbed planting technique because of its lower labor cost despite its lower productivity. Flatbeds do not require further bed preparation as in raised beds. This technique is also practiced in soils with good water retention yet high drainage, commonly in sloppy areas.

Over the years, significant advancements have been made in garlic planting technology. Rocha et al. (1991) developed a manually operated planter for garlic bulbs, mounted on two bicycle wheels. Park et al. (2000) introduced a garlic clove planter designed to plant garlic in an upright position on raised beds, with the blunt root portion directed toward the ground. In Thailand, Jarudchai et al. (2002) designed and developed a specialized garlic planter. Bakhtiari and Loghavi (2009) designed and tested a tractor-mounted row crop precision planter capable of planting three rows of garlic cloves on raised beds. What is common to these developed garlic planters is the effective metering mechanism.

However, no locally manufactured garlic planter is still available in the market. Imported garlic planters can be bought but for a high cost. Also, spare parts are not locally available if the planter parts need replacement. Dumaoal and Bato (2010) designed a pull-type single-row manual garlic planter with a rocker arm metering mechanism, capable of planting garlic cloves in a non-vertical orientation in a flatbed field. However, their machine is not adopted by the local farmers. Based on assessments, it has been determined that farmers require a straightforward garlic planter with an uncomplicated mechanism that allows for repairs and maintenance to be carried out by the farmers themselves. It is in this light that a simple metering device for a garlic planter is desired.

# MATERIALS AND METHODS

## Design of Metering Mechanism

In this context, a simple yet effective metering mechanism was developed. The metering mechanism was intended to be integrated into an experimental two-wheel, push-type planter designed specifically for planting garlic. The design allows garlic farmers to carry out the repair, maintenance, and replacement of parts on their own. Accordingly, farmers wanted a good percentage of singulation and relatively low occurrences of missed hills. It was also intended that the garlic planter deliver garlic cloves 17 centimeters apart based on the recommendation in Ilocos Norte. Based on its metering device, the garlic planter should have an ideal field capacity of 0.2 ha/hr (Gambari, et al. 2017). Arbitrarily, missed hills were kept at 10%

and below as there was no study found regarding the singulation in metering garlic cloves.

**Garlic Cloves for Testing**

The characteristics of cloves were determined. These include the garlic variety, average size, weight of 1000 cloves, and moisture content wet basis. Ten (10) randomly selected cloves were measured using a digital caliper for the average length, width, and thickness. Moisture content determination was done through the oven-dry method. Three samples of 1000 cloves were weighed and the average weight was recorded.

**Performance Evaluation**

Without a corresponding standard for evaluating the performance of a garlic planter, PAES 123:2001 and PAES 151:2015 were the nearest and were used as references to evaluate the performance of the garlic metering mechanism. The identified parameters affecting the performance of the garlic planter metering device were hopper capacity, garlic variety used, and planting distance.

Percent singulation and percent missed hills were calculated using the following equations:

$$\%\ singulation = (no.\ of\ single\ deliveries/meter\ count) \times 100$$

***Equation 1***

$$\%missed\ hills = (no.\ of\ missed\ hills/meter\ count) \times 100$$

***Equation 2***

where meter count is the number of cup deliveries for the trial.

Percent singulation and the number of missed hills were determined. This test was carried out at full, half, and one-fourth of the hopper capacity at the optimal picker speed. Picker speed is the linear speed of the chain conveyor with attached garlic pickers. For each trial, the drive shaft of the metering mechanism was turned ten revolutions at 20, 40, and 60 rpm with three (3) replicates at each speed. To determine the corresponding picker speeds, the following equation was used:

$$picker\ speed\ \left(\frac{m}{s}\right) = shaft\ \frac{rev}{min} \times \frac{50\ mm}{1\ rev} \times \frac{1\ min}{60\ s} \times \frac{1\ m}{1000\ mm}$$

***Equation 3***

Laboratory tests were done on a makeshift test rig. Laboratory tests included calibration for the metering mechanism and investigation of the pattern of cloves deposited.

The field performance test was conducted for two test fields. The first field measured 20m x 25m while the second was 36m x 14m, respectively. Both fields were prepared as follows: flatbeds, single pass plowed, no mulch before planting, and not wetted. A continuous pattern, turning strips at each end was implemented. The cloves used for field tests were the same as the ones used in the laboratory test. The field was prepared with a single pass plowing. Double-pass plowing caused excessive sinkage of the machine thereby settling for single-pass plowing. Two-meter row sections were randomly selected from the planter rows. For each two-meter section, the following were determined:

*distance between hills* – is the distance between two planted cloves; and

*number of missed hills* – a hill is considered missed when the distance between two hills is greater than 25 centimeters.

Other parameters that were measured and computed during the field performance test included the following:

a. actual travel speed; and
b. working capacity (ha/h).

**Design of Experiment and Statistical Analysis**

A 3-level, 3-factor full factorial design of the experiment was used to determine the effects of the previously mentioned factors affecting the performance of the metering device in terms of percent singulation and percent missed hills.

The Response Surface I-Optimal Linear and Quadratic models were used to determine the optimal picker speed of the metering device while maximizing singulation and minimizing missed hills. It was recommended using both linear and quadratic models to prevent aliasing.

## RESULTS AND DISCUSSIONS

### Garlic Sample Characteristics

The average length, width, and thickness of garlic cloves used in the study are 28.65, 14.65, and 11.82 mm, respectively (**Table 1**). The total weight of 1000 cloves measures 1835 grams on average (**Table 2**). The average moisture content (wet basis) of the garlic cloves was 52.78% (**Table 3**).

### Garlic Planter with the Proposed Metering Mechanism

**Figure 1** and **Figure 2** show the garlic planter with a simple metering mechanism and the fabricated prototype, respectively. The major components of the garlic planter include the frame, ground wheel, hopper, handlebar, furrow opener, cup conveyor, front wheel, and chain and sprocket transmission system. The frame supports all components of the machine. The ground wheel drives the metering device of the planter using a single-stage chain and sprocket transmission system. The garlic planter employs a chain conveyor with small metal cups attached at specified intervals. It picks up cloves from the hopper to the delivery chute. During the initial test, cloves tended to be crushed by the chain and sprocket system. Brushes were installed along the

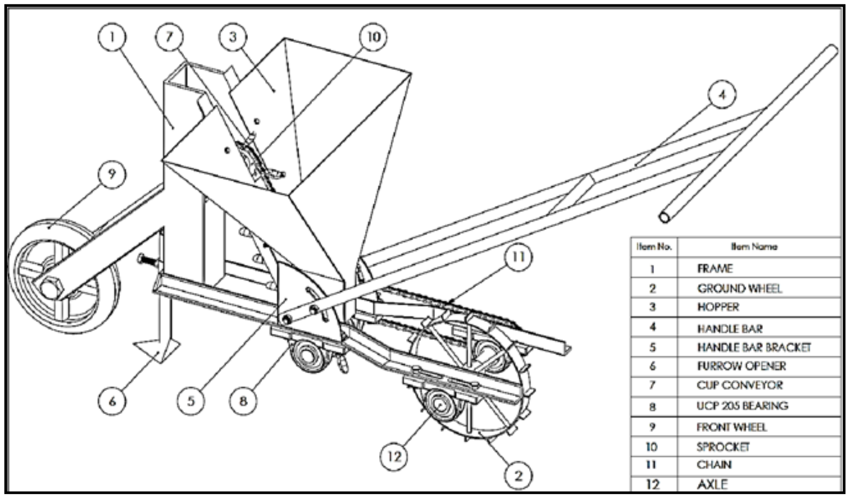


**Figure 1. Design of the garlic planter.**

**Figure 2. The fabricated garlic planter.**

**Table 1. Dimensions of 10 randomly selected garlic cloves used in the study.**

| PARAMETER | SAMPLE | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | Ave | SD | Var |
| Length (mm) | 30.4 | 29.5 | 26.6 | 25.7 | 27.9 | 29.5 | 28.8 | 28.8 | 31.7 | 27.6 | 28.65 | 1.7772 | 3.1583 |
| Width (mm) | 16.0 | 15.1 | 14.1 | 15.0 | 13.6 | 14.6 | 14.4 | 14.6 | 14.9 | 14.2 | 14.65 | 0.6570 | 0.4317 |
| Thickness (mm) | 13.5 | 10.0 | 11.0 | 13.0 | 9.7 | 10.8 | 12.8 | 12.1 | 10.8 | 14.5 | 11.82 | 1.5985 | 2.5551 |

conveyor to prevent clove damage and promote a single pickup.

**Determination and Selection of Sprocket Size for the Metering Mechanism**

The calculated forward speeds for the sprocket combinations are shown in **Table 4**. All combinations with acceptable forward speeds between 1.5 and 2.4 kph were checked for plant spacing. Based on the preference of local garlic farmers, only 14T and 16T sprockets, respectively, fit within the standard planting distance, as shown in **Table 5**. Results showed that using 16T as sprocket 2 yielded more consistent and less deviated planting distance. Hence, two (2) 16T sprockets were selected.

**Laboratory Performance Test**

According to PAES 123, the planter's hopper capacity and delivery rate must vary to test its laboratory performance. However, changing the delivery rate for the garlic planter is not possible, limiting the test parameter to hopper capacity only. This test used the optimal picker speed and the 16T sprocket as sprocket 2. This test determined the planter's performance at ten (10) revolutions of the metering device shaft (**Table 6**).

The results of the ANOVA showed that the machine's performance at full and half hopper capacity is comparable (**Tables 7 and 8**). At 25% hopper capacity, percent singulation significantly decreased while the percent missed hills increased. The results suggest that operators should refill before the hopper reaches 25% in the field test.

**Optimal Picker Speed**

Hills with more than one clove planted were considered hills with an incorrect number of cloves while missed hills decreased plant population and overall harvest. These two (2) parameters are affected by picker speed. Therefore, optimal picker speed was determined by targeting the least missed hill and high singulation percentage.

**Figure 4** shows that the optimal picker speed obtained was 0.037 m/s with a predicted percent

**Table 2. Weight of 1000 garlic cloves.**

| SAMPLE | INITIAL WEIGHT (g) |
|---|---|
| 1 | 1845 |
| 2 | 1825 |
| 3 | 1835 |
| Average | 1835 |

*SD = 10; Var = 100*

**Table 3. Moisture content wet basis data of sample garlic cloves.**

| SAMPLE | INITIAL WEIGHT (g) | FINAL WEIGHT (g) | MOISTURE CONTENT WET BASIS (%) |
|---|---|---|---|
| 1 | 28.7 | 8.3 | 52.31 |
| 2 | 29.2 | 7.9 | 53.25 |
| 3 | 32.2 | 9.5 | 52.79 |
| | | Average | 52.78 |

*SD = 0.4700; Var = 0.2209*

**Table 4. Corresponding planter forward speed for sprockets 1 and 2 combinations.**

| NO. OF TEETH SPROCKET 1 | NO. OF TEETH SPROCKET 2 | GEAR RATIO | PLANTER FORWARD SPEED (kph) |
|---|---|---|---|
| | 14 | 1.14 | 2.30 |
| | 16 | 1.00 | 2.01 |
| | 18 | 0.89 | 1.79 |
| 16T | 20 | 0.80 | 1.61 |
| | 23 | 0.70 | 1.40 |
| | 26 | 0.62 | 1.24 |
| | 30 | 0.53 | 1.07 |

**Table 5. Planting distance using 14T and 16T for sprocket 2.**

| PARAMETERS | SPROCKET SIZE | |
|---|---|---|
| | 14T | 16T |
| Average Planting Distance | 21.77 | 21.25 |
| Standard Deviation | 8.49 | 7.18 |

**Table 6. Laboratory performance test of garlic planter.**

| HOPPER CAPACITY | WEIGHT OF CLOVES (g) | HOPPER LEVEL (cm) | SINGULATION (%) | MISSED HILL (%) |
|---|---|---|---|---|
| Full | 1500 | 13.2 | 70.59 | 7.84 |
| Half | 750 | 9.1 | 74.51 | 5.88 |
| Quarter | 375 | 6.5 | 65.69 | 12.74 |

**Table 7. ANOVA of percent singulation.**

| GROUPS ANALYZED | P-VALUE AT 95% CONFIDENCE LEVEL |
|---|---|
| All capacities | 0.007* |
| Full and Half | 0.116NS |
| Half and Quarter | 0.003* |
| Full and Quarter | 0.06NS |

* *with significant difference*
NS *no significant difference*

**Table 8. ANOVA of missed hill percentage singulation.**

| GROUPS ANALYZED | P-VALUE AT 95% CONFIDENCE LEVEL |
|---|---|
| All capacities | 0.002* |
| Full and Half | 0.116NS |
| Half and Quarter | 0.002* |
| Full and Quarter | 0.02* |

* *with significant difference*
NS *no significant difference*

singulation of 71.27% (**Figures 4** and **5**) and a predicted missed hill at 5.88% (**Figures 4** and **6**).

**Field Performance Test**

**Table 9** shows the overall operational durations for each field. Operating durations include the working time, turn-around time, refill time, and maintenance time. Ten randomly selected 2-meter segments in both fields were examined for planting distance as presented in **Table 3**.

**Table 9. Descriptive statistics of planting distance for both fields.**

| STATISTICAL PARAMETER | FIELD 1 | FIELD 2 |
|---|---|---|
| Mean | 16.53 | 16.70 |
| Standard Error | 0.22 | 0.21 |
| Median | 16 | 16.50 |
| Mode | 14 | 18 |
| Standard Deviation | 2.31 | 2.17 |
| Sample Variance | 5.35 | 4.73 |
| Skewness | 0.35 | 0.28 |
| Range | 10 | 10 |
| Minimum | 12 | 12 |
| Maximum | 22 | 22 |
| Sum | 1851 | 1820 |
| Count | 112 | 109 |

Data show that the performance of the metering device of the garlic planter for both fields is almost identical. Therefore, the planter's performance is consistent throughout the field performance test. The planting distance for the missed hill to the adjacent hills is half of the distance between the two (2) adjacent planted hills. The standard deviation of planting distance is relatively high compared to the standard deviation of the planting depth. During drop-off, the cloves tended to bounce off the walls of the delivery chute. The construction of the delivery chute is relatively large since it supports the metering device. Two (2) possible paths of cloves during drop-off are in **Figure 7**. **Figure 7** shows the wireframe model of the machine's frame where the delivery chute is part of the structural support. The blue and red dashed lines inside the delivery chute are only two (2) of many possible paths of dropped cloves. The red dashed line represents a path resulting in a short planting distance. On the other hand, the blue dashed line represents a longer planting distance. The ideal course of a dropped clove is straight down the chute.

### Predicted Performance vs. Actual Field Performance

The machine's laboratory performance test involved three (3) trials using the optimal picker speed at full hopper capacity. Analyses of variance (ANOVA) determined the significant differences between the machine's predicted performance and actual field performance (**Tables 10 and 11**). The percent singulation of the planter during actual field testing was almost identical to that of the predicted value. However, the percentage of missed hills in the field setting (19.9%) was much higher than predicted (5.8%) (**Table 10**). The cloves tended to clump

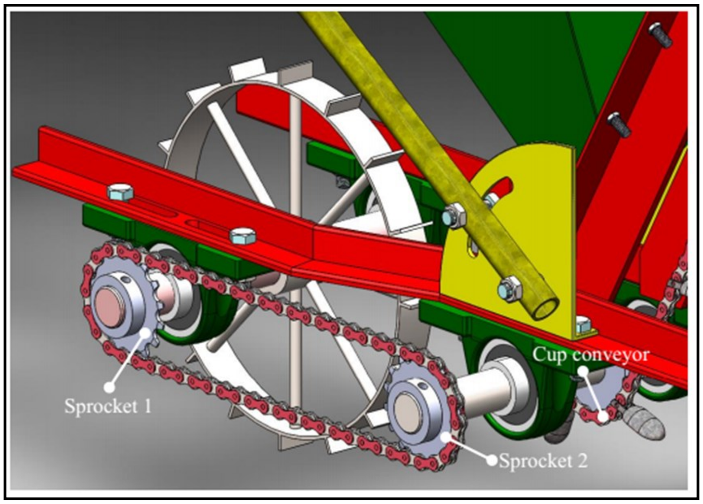


**Figure 3. Sprocket 1 and Sprocket 2 in the experimental garlic planter**

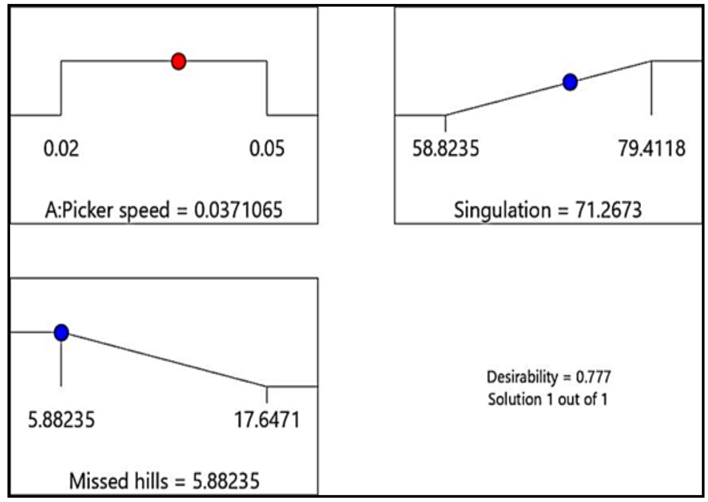


**Figure 4. Ramp graph showing the optimal picker speed and predicted percent singulation and percent missed hills.**

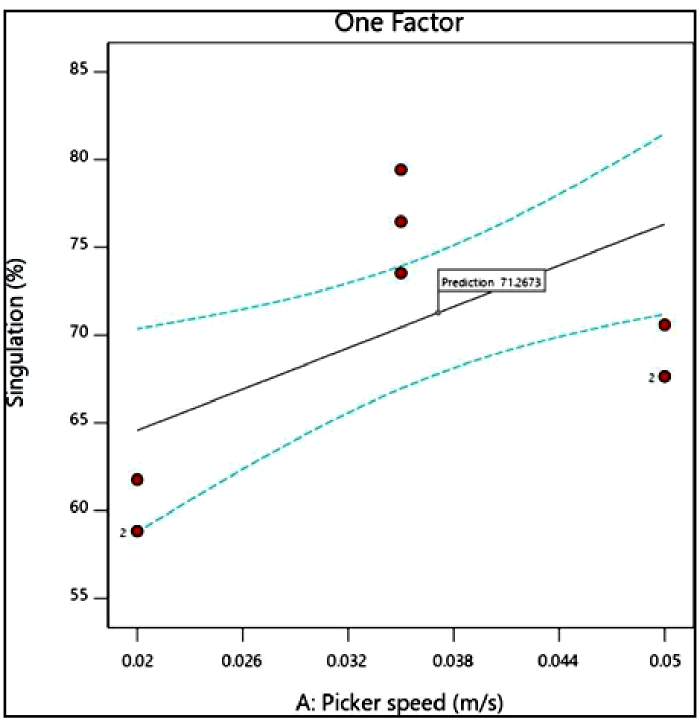


**Figure 5. Predicted percent singulation value using the optimal picker speed.**

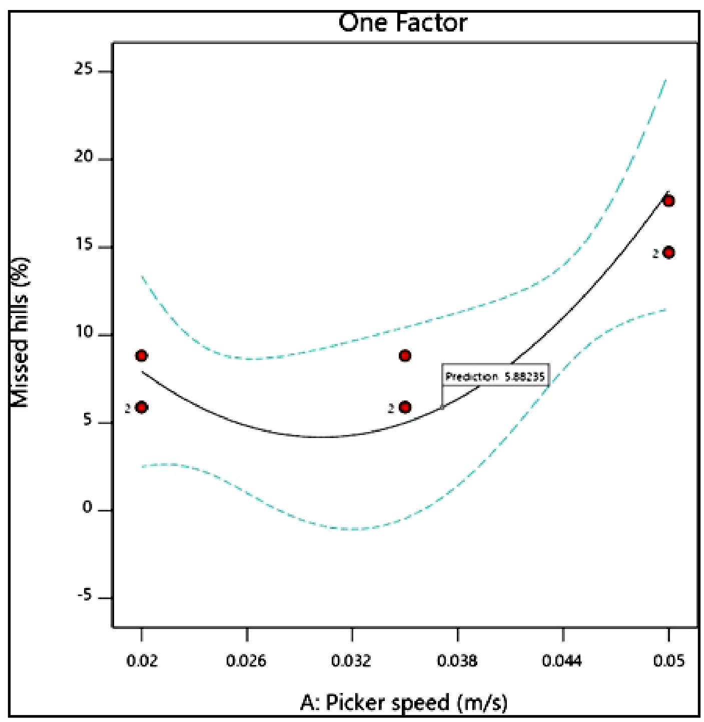


**Figure 6. Predicted percent missed hills value using the optimal picker speed.**

beneath the conveyor's chain during the test. This clumping limited the pickup of available cloves in the hopper. The clumping of cloves in the laboratory test was not very evident during the field test due to vibration. Vibration caused the cloves in the hopper to be constantly agitated, making the pickup more effective. As a result, the conveyor cups picked up more cloves during the field test; however, vibration also caused the cloves to drop more frequently from the picker cup back to the hopper. Double or triple clove pickups were frequent, but cloves dropping back to the hopper were frequent, resulting in higher missed hills. In the study by Bakhtiari and Loghavi (2009), the observed missing hills were 12.3% while that of Elgawad et al. (2012) ranged from only 0.2 to 1.8% (with forward speed of 1.40 to 4.73 km/h). On the other hand, in a study by Kang et al (2018), the observed missed hills ranges from 6.2% (medium-sized cloves) to 11.0% (small-sized cloves).

## CONCLUSION

The metering device of the planter uses a single-stage chain and sprocket conveyor with small metal cups attached at specified intervals. The cups pick up cloves from the hopper to the delivery chute. During laboratory testing, the optimal picker speed obtained was 0.037 m/s with a predicted percent singulation of 71.27% and a predicted missed hill at 5.88%. The designed metering device of the garlic

**Table 10. Predicted vs actual field performance of the metering mechanism.**

| PARAMETER | PREDICTED | ACTUAL |
|---|---|---|
| Percent Singulation (%) | 71.27 | 69.65 |
| Percent Missed Hills (%) | 5.88 | 19.90 |

**Table 11. P-value comparing the laboratory and field performance of the garlic planter in terms of percent singulation and percent missed hills.**

| PARAMETER | P-VALUE (95% CONFIDENCE LEVEL) |
|---|---|
| Percent Singulation | 0.1936* |
| Percent Missed Hills | 0.0063NS |

* *with significant difference*

NS *no significant difference*

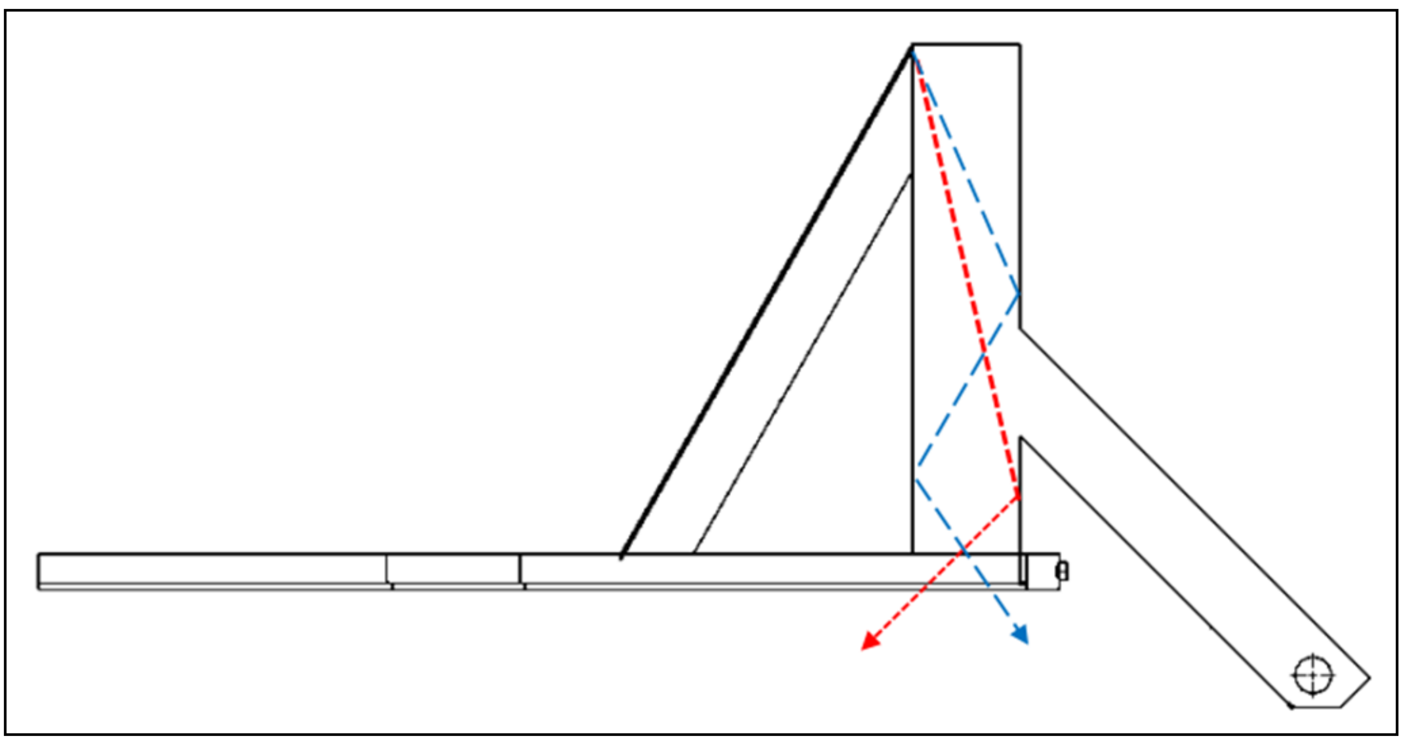

**Figure 7. Two (2) possible paths of a clove down the delivery chute during drop-off.**

planter performed as expected in terms of clove singulation, however, exhibited relatively high missed hills during field tests. The high missed hills were caused by the bouncing off of garlic cloves from the gathering cup due to vibration. Excessive vibration was not observed during laboratory tests but was very noticeable during field tests.

## RECOMMENDATION

An improvement to the cup design system is recommended. Vibrations should be minimized at the metering device section. The amplitude of the vibration is suggested to be quantified to plan for possible mitigation or reduction of the effect of vibration during actual planting. Immediate release of cloves into the delivery tube could also mitigate the high missed hills..

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