Development of a Tool to Apply Chemical Fertilizer for Pineapple (*Ananas comosus*) Cultivation

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Abstract

Pineapple (Ananas comosus) is a heavy feeder and needs more nutrients to get an optimum yield. Fertilizer application is problematic in all Pineapple cultivations mainly due to two reasons. On the one hand, there are spiny and pointed leaves and on the other hand, the place where fertilization needs to be applied. The fertilizer should be applied to the base of the leaves and is a laborious and annoying practice, especially when done manually in commercial cultivation. Therefore, there is a necessity to develop a convenient technique to facilitate the fertilizer application. Hence, an experiment was conducted at the University of Colombo Institute for Agro-Technology and Rural Sciences, Hambantota, Sri Lanka to develop a simple tool to apply chemical fertilizer at the base of Pineapple leaves. The tool was developed using PVC pipes, nuts, bolts, rubber bands, a spring and glue. All these items were assembled in an orderly manner to develop a smart and a simple tool to achieve the purpose. The height of the tool can be adjusted by changing the fertilizer loading component. A questionnaire survey was conducted among the pineapple cultivators to evaluate the usefulness of the tool. The weight, height, safety, efficiency, cost and overall acceptability were evaluated using a five-point Likert scale. Further, the developed tool was compared with manual fertilizer application to monitor the time taken to apply fertilizers and the labour cost using 20 pineapple plants at the same age. The independent sample T-test was used to test the significance at 5% level. The tool placed the recommended amount of fertilizer/plant in two pushes (5.1 ± 0.19g) and covered 20 plants with an efficiency of 326.84 ± 2.46%. And efficiency of the cost involvement of the tool was 305.84 ± 3.58%. The farmer responses indicated that the tool was a simple, portable, smart and user-friendly tool with more advantages.

Keywords:* *Applicator, Efficiency, Fertilizer, Pineapple, Tool

I. INTRODUCTION

One of the main commercial fruit crops grown in Sri Lanka is pineapple (*Ananas comosus*), which has a significant export market potential due to the country's ability to produce some of the best pineapples in the world. Due to a shortage of supplies and exportable quality, Sri Lanka, which ranks 34th among countries that produce pineapple, is unable to meet the rising demand for the fruit on domestic and international markets (Rupasinghe et al., 2016). Both in the lowlands and at higher altitude of up to 1,000 m above sea level, pineapples thrive in a temperature range of 18–32^{0}C. Despite being a drought-tolerant crop, pineapples will still bear fruit in years with annual rainfall between 650 and 3,800 mm. The growth environment, cultivation methods, and variety all affect pineapple quality (Hossain, 2016). Costa Rica, the Philippines, Netherland, USA, and Belgium were the top five pineapple exporters in the world in 2020. Total export quantity of 3.1 million tons in 2020, representing a 7.9 percent fall compared to 2019 (FAO, 2021). For pineapple, Sri Lanka's rank among global exporters was 36 and its market share in world pineapple market was 0.09 (Silva et al., 2023).

Nitrogen and potassium fertilization greatly impact pineapple fruit yield, organoleptic, and sanitary quality (Spironello et al., 2004). Nitrogen is essential to maintain high growth rates, and pineapple response to N fertilization is strong, making it possible to produce high yields with short growing cycles. Potassium vital role in fruit quality (Hepton and Bartholomew, 2003), and plants and fruits require large quantities of K. The K/N ratio is also essential to yielding and organoleptic quality build-up. Although recommended fertilizer quantities vary according to the cultivar. As recommended by DOA Sri Lanka, fertilizers for pineapple plants should be applied on initially one month after planting and thereafter every 3-4 months after planting at the rate of urea – 10g/ plant, TSP – 5g to 7g/plant and

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MOP – 15g/plant. Chemical fertilization thus represents a large part of total production costs.

Large-scale pineapple cultivation faces a challenge in fertilizer application. In Sri Lanka, manual application is the primary method of fertilizer application due to the difficulty of applying it to the leaf base. However, this method often causes hand injuries to farmers, which discourages them from using it. Therefore, there is a need to develop a simple tool to facilitate fertilizer application for pineapple farmers. An experiment was conducted with the aim of developing such a tool that could apply chemical fertilizers to the base of pineapple leaves and designing an efficient instrument for the precise application of fertilizer to pineapple plants, while ensuring the safety of farmers.

II. MATERIALS AND METHODS

A. Design Concept

The instrument we have developed allows for the targeted application of fertilizer to the base of pineapple plant leaves. The key components of this instrument include a 1.5-inch PVC fertilizer container, 1-inch PVC pipe, 0.75-inch PVC pipe, rubber band, fertilizer exhaust hole, spring, reducer, 45-degree barrier, and a fertilizer output PVC pipe. To use the instrument, fertilizer is loaded into the fertilizer container, which is then pushed into place and released. Subsequently, the fertilizer output hole opens, allowing the fertilizer to flow through the exhaust PVC pipe fixed at a 45-degree angle. This precise delivery method ensures that the fertilizer reaches the base of the pineapple leaves effectively. Once the fertilizer has been dispensed, the spring and rubber mechanism automatically return the fertilizer container to its original position, closing the fertilizer output hole securely. This instrument not only increases the efficiency of fertilizer application but also minimizes the risk of damage to farmers during the process.

An initial framework of the instrument (Figure 01) was designed using photoshop software (Coreldraw, 2019) to finalize the materials needed to develop the instrument.

B. Development of the Instrument

PVC pipes were selected with diameters of 1.5 inches and 0.75 inches, each measuring 80cm and 20cm in length, respectively (Figure 02). A hole with a diameter of 0.5 cm was drilled at the top end of the 1.5-inch PVC pipe, positioned 8cm from the top. A round wooden piece with a 6cm diameter was inserted into this hole until it reached the end of the pipe. To join the 1.5-inch and 0.75-inch PVC pipes, a reducer was used, securely fixing them together (Figure 02a).

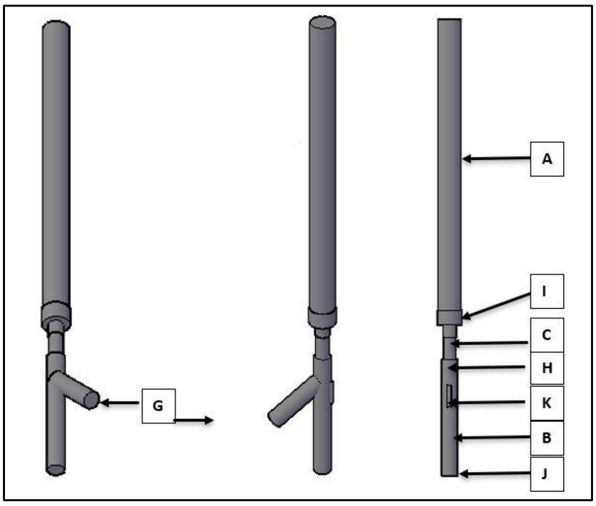

Figure 01: Initial framework of Developed Tool

A. Fertilizer container (1.5 inch PVC pipe)
B. 1 inch PVC pipe
C. 0.75 inch PVC pipe
D. Fertilizer exhaust hole (inside of the instrument)
E. Spring (inside of the instrument)
F. 45 degree barrier (inside of the instrument)
G. Fertilizer output PVC pipe
H. Rubber band
I. Reducer
J. Base
K. Screw

Another component involved a single piece of 30cm-long PVC pipe with a 1-inch diameter. An end cap with a 1-inch diameter was affixed to the bottom end of this pipe. Additionally, a hole with a 0.5cm diameter was drilled 8cm from the top end of this PVC pipe. In close proximity to this hole, another hole measuring 0.5cm in width and 5cm in length was created, also positioned 8cm from the top. This pipe was then inserted into the 0.75-inch diameter PVC pipe. A screw was fastened to the round wooden piece inserted into the 1.5-inch PVC pipe, and a rubber band was attached to the top end of the instrument. Lastly, a 1-inch PVC pipe, measuring 20cm in length, was selected and cut at a 45-degree angle. This cut piece was then attached to a hole in the instrument. The final assembled tool is indicated in Figure 02b.

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C. Working Principle

The rubber band is tightly fastened to the fixed piece, while the screw is connected to the movable piece. When the movable piece is pressed downward, it moves easily, but it returns to its original position with the aid of the rubber band. The open ends of both pieces meet together when the movable piece is pushed down. This action triggers the release of fertilizer, a process that occurs within seconds. The released fertilizer flows through the outlet end of the instrument, targeting the base of the pineapple crop. To utilize this tool effectively, fertilizer must be loaded into the fixed piece, which has a narrower PVC structure, creating the necessary pressure for the fertilizer to descend. By pushing the fertilizer container, minor pressure is applied to the long PVC pipes, facilitating the controlled release of the fertilizer.

Figure 02: a) Parts of developed tool; b) Final view of developed tool; c) Field evaluation of developed tool; d) applying fertilizer at the leaf base of pineapple plants

D. Operation of the Tool

About 500 grams of fertilizer was filled through the top opening of the tool. The tool is equipped with a handle that allows for easy movement from one location to another. The tool was placed at a distance of 20 cm from the base of the pineapple crop. The end of the tool with the fertilizer was precisely positioned on the base leaf of the pineapple crop. The handle of the tool was pressed and did it for a second. During this brief period, the required amount of fertilizer was effectively applied to the base leaf of the pineapple crop (Figure 02d). This straightforward process facilitated the efficient and precise application of fertilizer to the base of the pineapple crop, ensuring optimal nourishment for healthy growth.

E. Evaluation of the Developed Tool

The weight and length of the tool were measured using scales. Acceptability of the developed tool for its weight, height, safety, handling ability, fertilizer efficiency, cost incurred for the tool and overall acceptability were evaluated five-point Likert scale (1 – Highly acceptable, 2 – Acceptable, 3 – Neutral, 4 – Not acceptable and 5 – Highly not acceptable). The collected data were statistically analyzed using SPSS version 25 and descriptive statistics were explained graphically.

Further, a field experiment was conducted to evaluate the time taken to apply fertilizers and the cost incurred for operation (Figure 02c). The land (1 acre) was divided into 4 parts (4 replicates) and the developed instrument was tested 20 times and average values were taken for comparison and substituted in equation 1. The above variables were measured separately the for manual method and using the tool. The collected data were statistically analyzed using an independent sample T-test at 5% significance level.

Then, time efficiency and cost efficiency were calculated for the tool as follows;
Time efficiency was calculated by comparing time taken for fertilizer application using manual method and by using developed tool (E 1).

$$Time\ efficiency = \frac{Time\ taken\ for\ fertilizer\ application\ using\ manual\ method}{Time\ taken\ for\ fertilizer\ application\ using\ developed\ tool} \times 100\ \%\ \text{------E1}$$

Cost for labour was used to calculate the efficiency and it was calculated by comparing cost incurred for fertilizer application using manual method and by using developed tool (E 2).

$$Cost\ efficiency = \frac{Cost\ incurred\ for\ fertilizer\ application\ using\ manual\ method}{Cost\ incurred\ for\ fertilizer\ application\ using\ developed\ tool} \times 100\ \%\ \text{--- E2}$$

III. RESULTS AND DISCUSSION

A. Characteristics of the Developed Tool

The developed tool has been designed with specific attributes that make it particularly user-friendly for farmers. It weighs about 328 grams, which is remarkably light. This lightweight feature ensures that it can be carried and manipulated with ease by farmers regardless of their physical strength. Additionally, the tool's height is 1 meter, which falls within a practical range for ease of handling. This height is

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conducive to comfortable usage, allowing farmers to work with the tool without straining themselves or adopting uncomfortable postures. Height of the tool is adjustable by replacing the upper part (fertilizer loading component). The combination of its light weight and manageable height renders this tool highly convenient and accessible for all farmers, facilitating their agricultural tasks with efficiency and comfort.

B. Acceptability of the Developed Tool

Figure 03 indicates the user response for the developed tool. It was observed that the highest percentage (65%) of the respondents highly accepted the weight of the tool and the comparatively lowest percentage (35%) of the respondents accepted the weight of the tool. Further 55% of the respondents indicated that the height of the tool was highly acceptable and 35%. The lowest percentage (10%) of the respondents were neutral in tool height. Most of the respondents (75%) mentioned the safety of the tool is highly acceptable and 25% of the respondents were acceptable with the safety of the tool while handling.

Approximately 60% of the respondents expressed a high level of satisfaction with the instrument's handling ability, while the remaining respondents found the handling ability of the equipment satisfactory. Approximately 70% of the participants indicated a strong acceptance of the fertilizer efficiency of the recently created instrument in comparison to manual application. 30% of the responders acknowledged the fertilizer efficiency of the instrument. 65% of respondents expressed a high level of satisfaction with the cost of the instrument, whereas 35% agreed with its pricing. Ultimately, 60% of participants expressed a high level of satisfaction with the overall acceptance, while the remaining 40% indicated agreement (Table 01).

C. The Efficiency of Developed Tool

It was found that there were significant differences between the manual fertilizer application method and application using tool in terms of time required to apply fertilizers for 20 plants and labour cost (Table 2). It was found that approximately less time was consumed (39.3 seconds) to apply fertilizers for 20 plants using newly developed tool and 128.4 seconds consumed for the manual application. Furthermore, comparatively higher cost (1389.7) incurred for manual fertilizer application and lower cost (454.4 Rs.) was observed to apply fertilizers using tool.

Table 01: Descriptive Statistics for Performances of the Tool

Description	Mean	SD
Acceptability for the weight of the tool	1.35	0.49
Acceptability for the height of the tool	1.55	0.69
Acceptability for safety to the farmer when applying	1.25	0.44
Acceptability for handling ability of the tool	1.40	0.50
Acceptability for fertilizer efficiency of the tool	1.30	0.47
Acceptability for the cost of the tool	1.35	0.49
Overall acceptability	1.40	0.50

Values represent the mean ± standard deviation of a 5 point Likert scale (1 – Highly acceptable; 5 – Highly not acceptable).

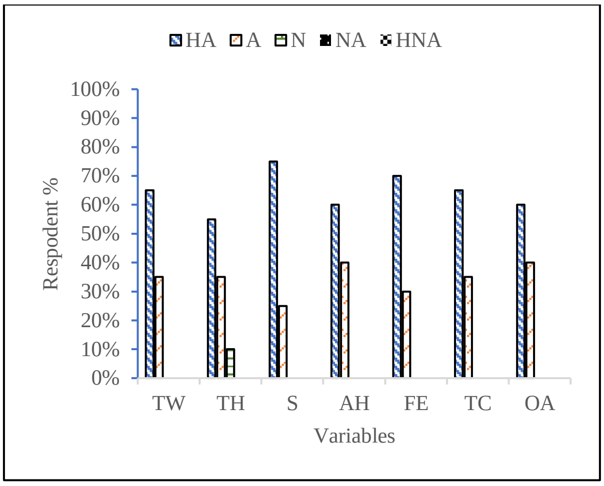

Figure 03 : Acceptability for the Developed Tool by the Respondents

(TW – Tool Weight; TH – Tool Height; S – Safety; AH – Ability for Handling; FE – Fertilizer Efficiency; TC – Tool Cost; OA – Overall Acceptability; HA – Highly Acceptable; A – Acceptable; N – Neutral; NA – Not Acceptable; HNA – Highly Not Acceptable)

Further, it was revealed that, an average of 5.1 g was released from the developed tool in a single push. There was 326.84 % of time efficiency and 305.84 % cost efficiency on the fertilizer application using tool compared to the manual.

When it comes to the safety of agronomic practices, the use of machinery is essential, especially when chemicals are used. With manual fertilizer application, the farmer has to bend down to apply the fertilizer every time it is applied, which is laborious. Therefore, the better ergonomics is also a decisive advantage of the instrument. When using the fertilizer spreader

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created, difficult bending positions are avoided. The operator, on the other hand, does not need to wear safety boots or overalls to avoid excessive contact with the fertilizer.

Table 02: Time and Labour Cost Efficiency

Parameter	Manual method	Using Tool	P value	Efficiency (%)
Time taken to for 20 plants (Sec)	128.44 ± 4.83	39.30 ± 1.18	0.000	326.84 ± 2.46
Labour cost (0.25 ac)	1389.74 ± 55.8	454.4 ± 13.6	0.000	305.84 ± 3.58

Values represent Mean ± Standard error of 4 replicates. Each replications contained 20 plants. $P<0.05$ is significant at 0.05 level.

Some regions still prefer manual application because they feel mechanical applicators waste fertilizer since they lack a speed feedback system to change the rate at which they apply the fertilizer. To satisfy crop nutrient needs, manual fertilizer application is frequently not tailed but rather maintained constant throughout time or over vast areas (Xu et al., 2017). This contributes to fertilizer misuse, which runs counter to ecologically friendly agriculture and results in imbalanced, ineffective fertilization and low economic returns. In addition, excessive and improper fertilization results in low nutrient use efficiency (Qin et al., 2013), which has an adverse effect on the environment by contributing to greenhouse gas emissions (Feng et al., 2013), land degradation, and freshwater pollution (Guo et al., 2010; Reidsma et al., 2013).

There should be consistency between doses administered at different times of fertilizer application. The goal of fertilizer application is to accelerate plant growth. Once the harvest schedule is established, there may still be plants that are not ready for harvest as uneven fertilization results in different harvest schedules for each tree (Moreno et al., 2017). The problem of fertilization is one that many researchers in the agricultural industry are working to solve. Making a fertilizer spreader automation tool is a way to distribute fertilizer quickly, correctly and precisely. However, in actual application, this device is still ineffective due to its non-adjustable dosage, operational clogging, and inaccurate fertilizer dispensing dose. According to Jinfeng et al. (2018), Yinyan et al. (2017), and Zhu et al. (2018), the main disadvantage of using an applicator is that it has very little flexibility, stability, and dose, which has poor in uniformity and discharge rate.

IV. CONCLUSION

An innovative tool has been developed to address the challenges associated with fertilizer application in pineapple cultivation. The device was designed to be simple but effective and received positive feedback from farmers following a field evaluation that compared its performance to manual application methods.This validation highlights the tool's potential for improved efficiency in the field. However, further testing is required in different regions of the country before the tool can be successfully rolled out to pineapple farmers across the island.

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