Development of a pull-type onion (Allium cepa L.) sowing machine for seedbed

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Abstract. The conventional sowing method of onion seeds offers great wastage and laborious. This study aimed to develop a pull-type onion sowing machine for seedbed to optimize the sowing of seeds, reduce labor cost, yields better quality onion seedlings, and increases income of onion farmers. The machine was tested and evaluated, in comparison with manual sowing of onion seeds, in terms of seed delivery rate, effective field capacity, field efficiency, seeding efficiency and drawbar power. The cost of sowing seeds using the machine was also determined. Results indicated that machine's delivery rate was significantly reduced to 5.33 g/m^2 from 11.35 g/m^2. This resulted to reduction in the quantity of seeds sown for a one-hectare onion production area by about 4-5 cams (1.6 to 2 kg). Machine's field capacity (375.45 m^2/h) was higher than of manual sowing (25.51 m^2/h). Field efficiency at 86.94% is higher than 60% threshold given by PAES [3]. The seeding efficiency of 89.70% was statistically the same with three seeds per 25 mm hill spacing. The drawbar power was found out to be 0.15 5kW. The cost of the machine is $1,666.67 with a break-even quantity of 9,226.9 m^2 or 138.11 cans of onion seeds in 0.62 years.

1 Introduction

Onion (*Allium cepa* L.), locally known as "sibuyas", is commonly used as condiments to add flavor to food. It is one of the important culinary ingredient in the world and considered as medicinal plants used to cure cough, obesity, osteoporosis, diabetes, insomnia, hemorrhoid, constipation, heart disease and other diseases because onions are rich in vitamins and minerals that are essential to our body [4].

The Philippines who ranked 59th among 175 countries in world production of dry bulb onions, has the majority of its produce in Nueva Ecija with 73,911.12 MT or 99.99 percent

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of the region's total output. The onion varieties planted in Nueva Ecija are red onion, yellow or white onion and shallot.

Direct seeding and transplanting are both adopted in the country. In direct seeding, it is planted directly into the field by manual broadcasting at higher seeding rate and labor requirement. Some developed countries uses mechanical direct seeders, however, these are quite expensive and uses high seeding rate. In transplanting, seedlings are started from seed or bulb in a seedbed and transplanted 45 days after sowing. Transplants are noted to have more advantages on economic use of seed, selecting healthy and vigorous seedlings, saving weeding and watering efforts during the early weeks of plant growth, and it also enable the farmers to attend to the seedlings in a compact area [1].

Transplanting is more popular in Central Luzon. The widely cultivated bulb onions, the red creole and yellow granex are grown from seeds, while multiplier onions (shallot or native onion) are raised from bulbs which produce multiple shoots, each of which forms a bulb. About 60.27 percent of the onion farmers cultivate red onion seeds while multiplier onion was planted by 39.73 percent.

In order to reduce the use of seeds for a certain production area, one of the solutions is to practice mechanical sowing of seeds instead of broadcasting where there is usually uneven distribution of seeds. Mechanical sowing of the seeds in the seedbed is necessary in order to distribute uniformly the seeds to produce a relatively uniform size of seedlings, lessen the amount and cost of seeds and man-day requirement of seed sowing. Hence, there is the need to design a seed sowing machine that will be able to sow seeds uniformly to produce robust onion seedlings which can possibly minimize wastage of small and very thin-stemmed seedlings during transplanting operation.

2 Materials and methods

2.1 Design of the machine

The machine was designed to sow seeds in 18 rows in a well-prepared 1 m width seedbed, the seed metering mechanism which sow seeds with a spacing of about 8 mm was ground-wheel driven while it is pulled by two-persons on the opposite side of the seedbed. The machine was composed of seven major components, namely: the handle, seed metering, guide wheel, furrow opener, frame, transmission system and furrow closer. The sizes of the different machine elements that comprise the components were designed based on the estimated loads and allowable stresses of the selected materials of construction. Design plan was drawn using Solidworks software.

2.2 Fabrication of the machine

Based on the approved design plan, an accredited local machinery fabricator was commissioned to do the fabrication of the machine. Simple and local manufacturing technologies were employed on most of the component parts of the machine. The vertical seed metering plate, however, was fabricated using computer numerical controlled machine (CNC). Step by step processes were: measuring, cutting, and bending of the various parts of the stainless sheet, and angle bar, drilling of holes for bolts, rapid prototyping for seed plate, joining of different assemblies by bolts, nuts, and welding, and assembly of the whole machine, finishing, and painting.

2.3 Performance test and evaluation

Based on the methods of test for agricultural machinery seeder and planter **[**3**]**, the parameters evaluated included the following**:** seed delivery rate, effective field capacity, field efficiency, seeding efficiency, and drawbar power**.** The experiment was set to compare the parameters for the manual seeding and mechanical seeding using the designed onion seeder using t-test comparison after 3 replications for each method**.**

2.4 Cost analysis

The cost analysis included the calculations of annual cost of operation: fixed and variable costs, break-even point, unit cost of sowing seeds using the machine (Php/unit area) and payback period, in case the machine shall be used for custom service operation**.**

3. Results and discussion

3.1 Description of the manually-operated onion seeder

The eighteen row onion sowing machine for seedbed as shown in Figure 1 which consists of handle, seed metering, guide wheel, furrow opener, frame, transmission system and furrow closer. The handle is used to pull the machine in both ends, as it was pulled it transmit rotation by chain and sprocket to the seed metering device which is a vertical seed plate which scoops and deliver the seeds into the opened furrow by furrow opener with the aid of guide wheel and followed by furrow closer which covers the seeds being sown.

Fig. 1. Onion sowing machine for seedbed.

3.2 Performance of the machine

The performance of the machine was summarized in Table 1. The seed delivery rate of the machine averaged 5.53 g/m^2 and this was significantly lower than manual sowing (11.35 g/m^2). Sowing seeds in a 400 m^2 seedbed, good for one-hectare onion production farm, the difference indicated that the 8-10 cans (400 g/can) of onion seeds sown using the manual

method was significantly reduced to only about 6 cans of seeds with the use of the mechanical onion seeder. This will cause a reduction of cost of seeds by about 25-40% in a one-hectare onion production farm.

The mean effective field capacity of manual operation was 25.51 m^2/h which was significantly lower than that of the mechanical seeding using the machine having a mean capacity of 375.36 m^2/h. The result also trimmed down labor requirement of seed sowing from 16 man-hours for manual method of sowing seeds to only 2.14 man-hours per 400 m^2 area of seedbed when the mechanical seeded was used.

In the one-sample t-test analysis of the field efficiency of mechanical sowing when compared with the 60% required minimum efficiency for tractor power-driven seeder-row crop planter, the result confirmed that the field efficiency of mechanical sowing having a mean of 86.94% was significantly higher than 60%, hence, in terms of field efficiency, the machine passed the PAES minimum efficiency standard [3]. Likewise, the one sample t-test comparing seeding efficiency of 89.70% by the machine to the expected seeding efficiency of 100% (3 seeds per 25 mm) also indicated that both were statistically equal. It means that seed distribution had an average hill seed spacing of 8 mm just the same with the desired three seeds in every 25 mm. This result offered at least good quality seedlings assuming other factors to be the same.

The mean seed density of the manual sowing (2863 seeds/m^2) was significantly higher than in mechanical sowing (1200 seeds/m^2). Considering an onion plant population of 400,000 plants/ha [2], it only needed 1000 seeds m^2 in the seedbed and the mechanical seed sowing machine mean seed density was much closer than that in manual sowing. Using the machine would minimize the wastage of unnecessary seeds and low-quality seedlings because of the overcrowding per m^2; therefore, a reduction of cost intended for seeds was expected.

The drawbar power of 0.155 kW exerted by two persons was measured to pull the seed sowing machine. When power exerted by each person was computed, this is slightly higher than the average power of two persons (0.15 kW) considering the average human power of 0.0746 kW (0.1 hp) for continuous work.

Table 1. Machine performance versus the manual sowing.

Machine Parameters	Mechanical Sowing	Manual Sowing/Method
Seed delivery rate	5.33 g/m^2	11.35 g/m^2
Effective field capacity	375.36 m^2/h	25.51 m^2/h
Field efficiency	86.94 %	
Seeding efficiency	89.70 %	
Seed density	1200 seed/m^2	2838 seed/m^2
Drawbar power, kW	0.155 kW	

3.3 Cost analysis of the machine

The onion sowing machine costs $1,666.67. Based on the cost of use equation, assumption used (Table 2) and a custom rate of sowing seeds manually at $0.034/$m^2$, the break-even point (Figure 2) would be when the machine was operated in a seedbed area of 9,227 m^2 per

year. Using the machine for custom service operation at a custom rate of $0.034/m^2 of seedbed area and at annual hours of 264 h would yield an income of about $2,678 per year. Hence, the computed payback period for the investment to be recovered would only be 0.62 years.

Table 2. Calculated data and assumption used for economic analysis.

Particulars	Total price
Purchase price ($)	1,666.67
Salvage value (%)	10
n, years	10
R&M, % P/100 h	5
rate of interest, %	10
TIS, %	2
Labor cost, P/day	6.86
Annual hours, h/year	264
Capacity, m^2/h	375.45
A. Fixed cost	
Depreciation	150.00
Int on inv	91.67
TIS	33.34
Total annual fc,P/yr	275.00
B. Variable cost	
R & M	0.83
Labor	0.86
Total vc, P/h	1.69
Break-even point	9, 227 m^2/yr

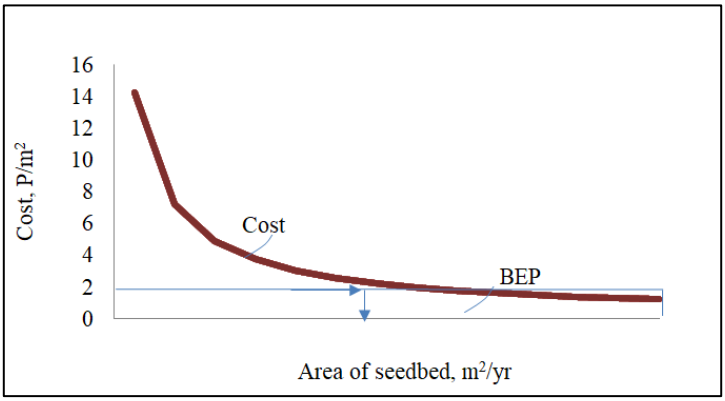

Fig. 2. Cost curve of using the machine.

4 Conclusions

Based on the results of the study, the following conclusions were made:

1. The concept and mechanism of developed onion sowing machine have proven to be effective to reduce labor, time, and use of seeds;
2. It can be fabricated using locally available materials at local machine shop except for the seed plate made by Computer Numerical Control;

3. Seed delivery rate was 5.33 g/m^2 which is lesser compared to manual accounting to 11.35 g/ m^2. Effective field capacity for manual sowing was 25.51 m^2/h, and 375.45 m^2/h using the machine. Field efficiency of onion sowing machine garnered 86.94% while seeding efficiency was 89.7%; and,
4. The total actual cost of fabrication of the machine is $1,666.67. It will be needed to sow 9,227 m^2 in a year to break-even the cost; enough to return the investment in one year.

References

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