Performance evaluation of multi-row onion seeder

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Abstract: There are several inefficiencies in the present direct seeding methods of onion that are being practiced in the Philippines. This study aimed to address these inefficiencies by developing and evaluating a tractor-hitched mechanical seeder that could efficiently distribute and plant onion seeds and reduce production cost.

Machine development was done from 2013-2016 and laboratory and extensive field evaluations in farmers' farms were carried out in 2016-2017. A 10-row, tractor-hitched and drill type onion seeder was developed which is capable of opening furrows, metering and delivering the seeds to the furrows, covering the seeds and firming the seedbed. The machine was evaluated in terms of its technical performance following the prescribed testing methods of PAES 123:2001. The seeder had a planting capacity of 0.41 ha h^{-1} and a field efficiency of 77.23%, which was higher than 60% field efficiency standard set by PAES for mechanical seeder. With a capacity of 0.41 ha h^{-1}, time and labor requirement for planting were significantly reduced with the use of 10-row onion seeder when compared to two-row onion seeder (0.21 ha h^{-1}, $p<0.05$) and manual broadcasting (0.35 ha h^{-1}, $p<0.05$). Percentage of seedling survival 24 days after first irrigation was comparable to the farmers' practice of manual broadcasting and using 2-row seeder. In areas using 2-row onion seeder, the use of 10-row onion seeder was found to substantially increase plant population which can potentially increase yield. For areas where manual broadcasting method is practiced, the 10-row onion seeder could significantly reduce the use of seeds from 7.68 to 4.94 kg ha^{-1}, thereby, reducing production cost. As a proof of its innovativeness, the application for patent of the machine has been accepted by the Intellectual Property Office (IPO)-Philippines in 2017.

The study also identified and verified the factors that should be considered to operate the machine efficiently. The 10-row onion seeder has considerable potential to increase onion yield and reduce production cost. It is recommended that early promotion and extension of the technology could start and focus in onion areas where direct seeding method has already been practiced. A more extensive pilot testing of the technology is recommended not only to validate the financial benefits of using the technology but also to demonstrate and create awareness of the presence of an alternative technology.

Keywords: bulb onion, seedling establishment, onion seeder, field performance, direct seeding

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1 Introduction

Onion (*Allium cepa* L.) is one of the Philippines' major economic crops which is valued for its culinary importance. The country's annual average production (2012-2016) is 153,316 MT with an estimated value of USD 70.13 M (PSA, 2017). Bulb onions in the Philippines are primarily produced from seeds and transplants. PSA (2014) reported that 78 percent of the onion farmers in major producing provinces practiced transplanting seedlings while the remaining 22 percent practiced direct seeding method. Direct seeding is done by manual broadcasting and by using farmer-designed two-row onion seeder. Direct seeding practice using the broadcasting method is costly for it requires 6.75-9.00 kg ha^{-1} of seeds as against the average requirement of 3.60-4.50 kg ha^{-1} using the transplanting method (Dela Cruz et al., 2014). On the other hand, the direct seeding

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method using a locally-designed manually-operated seeder plants is only about 50 percent of the total area intended for planting. The manual broadcasting method used twice the quantity of seeds and therefore spent twice the cost of seeds compared to the transplanting method. Additionally, the use of two-row seeder in Nueva Ecija did not maximize the use of area thereby to reduce the quantity of harvest per unit area (Idago et al., 2014).

According to Philippine Rural Development Project (PRDP) (2014), the cost of labor following the transplanting method constitutes 42 percent of the total cost of producing bulb onion. Seedling establishment following the transplanting method requires 43.76 person-days ha^{-1} (PSA, 2014) while the labor requirement for direct seeding is less than 1 person-day ha^{-1}. The significantly lower labor requirement from transplanting to direct seeding method for bulb onion is one of the major reasons for the adoption of direct seeding method by farmers in some of the major production areas where labor is not only scarce but also costly (Dela Cruz et al., 2014).

The cost of seeds constitutes 18 percent (average of 2011-2015) of the total production cost of bulb onion (PSA, 2016). As for the high cost of seeds and high seeding rate in manual broadcasting method and the lower production per unit area due to lower plant population using the two-row seeder, a machine should be developed to efficiently plant onion seeds and to maximize the productive use of land area. For these reasons, an onion seeder was designed and evaluated to address the inefficiencies in direct seeding systems involving broadcasting and two-row manually-operated seeding methods.

The main objective of this study was to develop and assess the performance of a tractor-trailed mechanical onion seeder. Specifically, the study aimed to: (a) develop an onion mechanical seeder, (b) determine its technical performance under the laboratory and field conditions, and (c) identify the operating requirements of the machine.

2 Methodology

2.1 Seeder specifications and schematic diagram

The multi-row onion seeder has two models, namely: 10-row model and 12-row model. It makes two beds and produces five or six rows in each bed in one passing. The 10-row model is hitched to a two-wheel tractor while the 12-row model is hitched to a four-wheel tractor.

The number of rows is adjustable depending on the need of farmer-users which is most often dictated by the variety of onion to be planted. For this study, the performance of the multi-row onion seeder adapting 10 rows in one passing was evaluated. Figure 1 shows the schematic diagram of the multi-row onion seeder.

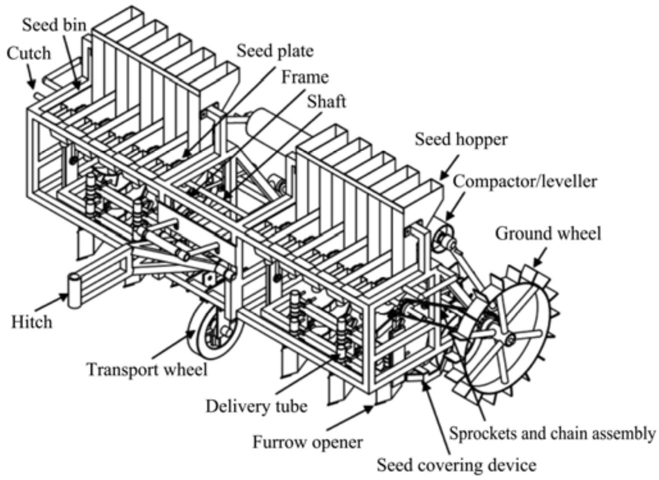

Figure 1 Schematic diagram of the multi-row onion seeder (10-row model) showing the major parts

The prototype onion seeder has three major components, namely: soil-engaging, seed metering system and distribution components. The functions undertaken by the soil-engaging components include opening the furrow, covering the seed and firming the seedbed. On the other hand, the functions undertaken by the seed metering and seed distribution components include those associated with metering the seed and delivering the seed to the furrow. The seeder's specifications and major parts and its function are shown in Tables 1 and 2, respectively.

Table 1 Seeder classification and specifications

Particular	Specifications
Classification	Multi-row onion seeder; number of rows can be adjusted until 12-rows
Labor requirement	one operator & one laborer
Metering mechanism	Ground wheel-driven
Construction	Steel and plastic
Dimensions	125 cm×180 cm×70 cm (L×W×H)

Table 2 Parts and function of the multi-row onion seeder

Parts	Functions
Seed plate	Selects seeds from the seed lot and discharges it at a predetermined rate
Seed delivery tube	Conveys the seed from the seed bin to the furrow opener
Furrow opener	Opens the furrow to the required depth into which the seed is placed
Seed covering device	Drags loose soil into the furrow to cover the seed after placement
Compactor/leveler	Firms the loose soil that covers the seed in a furrow and at the same time levels the seedbed
Frame	Structure that holds the parts of the seeder and attachment to the prime mover

2.2 Research design

The laboratory evaluation of machine performance adopted a single-factor experiment in complete randomized design with three replications. The variables tested were the ground wheel speed and the hopper capacity. Field evaluation adopted a single-factor experiment following replicated measure t-test design.

The study was conducted in the Crop Processing Laboratory and Experimental Field Station of the Philippine Center of Postharvest Development and Mechanization situated in Nueva Ecija, Philippines for the period of 2015-2018.

2.3 Laboratory performance test

Following the Philippine Agricultural Engineering Standard Method of Test for Seeder (PAES, 2001), laboratory and field performance tests were conducted to establish the technical performance of the multi-row onion seeder.

Before operating the multi-row onion seeder in actual field condition, the metering mechanism of the seeder was evaluated in the laboratory to determine the seed delivery rate at different ground wheel speeds and hopper capacities. The test was performed at full capacity (500 g/hopper), half capacity (250 g/hopper) and one-eight capacity (62.5 g/hopper) of the seeder’s hopper capacity and operated at three different forward speed settings of 3.0 km h^{-1} (44 RPM), 3.5 km h^{-1} (51.5 RPM) and 4.0 km h^{-1} (59 RPM). Each treatment was replicated three times.

The seeder was jacked-up and the drive wheel of the metering mechanism was rotated in a number of revolutions corresponding to the ground wheel speed for one minute. The seeds discharged by each of the seed plate were collected in polyethylene bag placed at the end of the seed discharge tube. The seed quantity delivered by each seed plate from the bin was weighed using an electric weighing scale. Similar procedure was adopted for the different speeds of the ground wheel. Three replications were done for each setting.

2.4 Field performance test

Field performance evaluation was done at PHilMech Headquarter and in major onion producing areas such as Nueva Ecija and Pangasinan. The following data were gathered following the methods specified under PAES 123:2001, such as:

a. Actual delivery/seeding rate – It is the amount of seeds scooped and delivered by the seed metering device of the mechanical seeder at a specified operating time or a specified planting area. Seeding rate can be computed using Equation (1).

Seeding rate (kg ha^{-1}) = [Weight of seeds delivered or planted]/Area planted (1)

b. Actual field capacity (AFC) – It is the actual rate of land planted/direct seeded in a given time, based on total field operating time. Field capacity was calculated using Equation (2).

AFC (ha h^{-1}) = [Total area planted]/Total operating time (2)

c. Theoretical field capacity (TFC) – It is the rate of the machine to operate at its full rated speed and width and can be calculated using Equation (3).

TFC (ha h^{-1}) = Speed of the machine × width of the implement (3)

d. Field efficiency (FE) – it is defined as the percentage of time the machine operates at its full rated speed and width while in the field and can be computed using Equation (4).

FE (%) = [Actual field capacity (AFC)/Theoretical field capacity (TFC)] × 100 (4)

e. Fuel consumption (FC) – It is the amount of fuel consumed by the machine at a given operating time and can be calculated using Equation (5).

FC (L h^{-1}) = Amount of fuel consumed/ Total operating time (5)

2.5 Evaluation of seedling performance

The seedling performance as a result of the planting method was also evaluated. As a reference point, the germinability of the seed stock used in evaluating the seeder was firstly tested. Each batch of seeds were tested in four replications, with 100 seeds per replication. The seeds were germinated in petri plates lined with filter paper and allowed to germinate in 12 days. This information were used in correcting field seedling survival. The germination percentages of the seeds were found to conform with the germinability indicated in the label of the seed container.

a. Percent seedling survival - A minimum of 1000 m^2 experimental area was used for each field testing sites. Normal seedlings that germinated 12 and 24 days after first irrigation (DAFI) were counted. A crisscross set-up of 10 sampling frames were established at each of the field testing area. Each frame has an area of 2 m^2 (1.6 m× 1.25 m). Seedling survival was computed using Equation 6. Normal seedlings are those that emerged from the soil 12 to 24 days after first irrigation with well-developed shoot axis consisting of elongated hypocotyl.

Seedling survival (%) = (Normal seedlings that emerged 12-24 DAFI)/No. of viable seeds corrected based on seed germination) × 100 (6)

2.6 Verification of performance in farmer's fields

The performance of the multi-row onion seeder was verified under farmers' conditions and compared with the traditional practice of direct seeding using manual broadcasting (Pangasinan practice) and using a locally-fabricated two-row manually-operated seeder (Nueva Ecija practice).

2.7 Method of analyses

The data obtained from the laboratory test were analyzed using one-way analysis of variance (ANOVA) and Scheffe test for comparison of treatment means. On the other hand, the performance indicators measured during the field test were compared following the independent t-test. The Statistical Package for the Social Sciences (SPSS) software was used in the computation of the performance indicators.

3 Results and discussion

3.1 Laboratory performance

The seeding rate of each hopper was determined, replicating the observations three times for each different ground wheel speed and hopper capacity. Across the different ground wheel speed and hopper capacity, the mean weight of onion seeds delivered in one hour was 11.99 kg (Table 3).

ANOVA indicated that the individual effect of hopper capacity and ground wheel speed significantly influenced seed delivery rate (p<0.05). Differences in seeding rates were not significant when the hopper was fully filled up (13.34 kg ha^{-1}) until the hopper was half-filled (13.28 kg ha^{-1}). Significantly lower seeding rate (9.37 kg ha^{-1}) was observed when the level of the seeds in the seed hopper reached 1/8 of its full capacity (62.5 g left in the hopper). On the other hand, highest seeding rate was observed when the speed of the ground wheel was set at 3.0 kph (13.06 kg ha^{-1}). Ground speeds of 3.5 and 4.0 kph resulted to significantly lower seeding rates of 11.94 and 10.98 kg ha^{-1}. The observed differences in seeding rates between the 3.5 and 4.0 ground speeds were not significant.

Table 3 Seeding rate (kg ha^{-1}) of the multi-row onion seeder as affected by its ground wheel speed and hopper capacity when tested at laboratory condition; 2016

Hopper Load	Ground Wheel Speed (kph)			Mean
	3.0	3.5	4.0	
1/8 level or 62.5 g/hopper	10.99	8.11	9.00	9.37^b
1/2 level or 250 g/hopper	14.12	13.85	11.86	13.28^a
Full level or 500 g/hopper	14.09	13.85	12.08	13.34^a
Mean	13.06^a	11.94^b	10.98^b	11.99

Note: Mean (s) with the same superscript letter are not significantly different (p<0.05).

Fully loaded to half-filled hopper gave a seeding rate that did not differ significantly while 1/8 filled hopper gave significantly lower seeding rate. This implied that the amount of seeds in the hopper should be replenished before it reached the level of 1/8 of the hopper capacity so that seeding rate would not be significantly reduced. During the last stage of seeding operation when the level of the seeds was reduced to 1/8 or lower, a strategy should be devised to maintain constant delivery rate. The results of laboratory test provided the information on machine factors that should be considered in the conduct of field evaluation and in future operation of the machine.

3.2 Field performance

After the laboratory test, field performance evaluation was done in seven locations in Nueva Ecija and Pangasinan where direct seeding is being practiced. Across several locations and different types of soils, the mean values and the ranges of the important technical indicators were gathered and shown in Table 4. Following the prescribed area of testing which is a minimum of 1,000 m^2, the effective field capacity, field efficiency, fuel consumption and seeding rate of the multi-row onion seeder were found to be 0.41 ha h^{-1}, 77.23%, 4.80 kg ha^{-1}, and 2.45 L ha^{-1}, respectively. The field efficiency meets the minimum standard set by PAES which is 60% for mechanical seeder.

Table 4 Summary of the field performance test conducted in seven locations in Pangasinan and Nueva Ecija; 2016-2017

Particular	Mean values across farms	Range
1. Area (m^2)	1,158	1,025-1,478
2. Time of operation (min)	17.58	11.85-26.4
3. Speed (kph)	3.35	2.75-4.34
4. Effective field capacity, ha h^{-1}	0.41	0.31-0.58
5. Theoretical field capacity, ha h^{-1}	0.53	0.44-0.69
6. Field efficiency, %	77.23	64.85-89.08
7. Seeding rate, kg ha^{-1}	4.80	3.77-5.59
8. Fuel consumption, L h^{-1}	1.0	0.53-1.52
L ha^{-1}	2.45	1.59-2.85
9. Type of soil in testing farms	Clay loam, sandy loam, silty clay	
10. Travel pattern	Headland; width of 1.15-1.67 m	
11. Power source	Two-wheel tractor; 6-7 kW	

The average seeding rate obtained in the laboratory trials was higher (11.99 kg ha^{-1}) than the seeding rate obtained during the field trials (4.80 kg ha^{-1}). Under field conditions, several factors were at play which affected the seeding rate such as the manner of land preparation, soil types, soil moisture content, and the machine used to pull the seeder which differed among the farmer-cooperators. The trend of increasing seeding rate with decreasing forward speed was also observed during the trials.

3.3 Multi-row onion seeder versus farmer's practice

3.3.1 Capacity and labor requirement

The field performance of the multi-row onion seeder was also compared with the direct seeding methods practiced by farmers in terms of actual field capacity and seeding rate. The multi-row onion seeder was separately compared with the manual broadcasting and with the 2-row manually-operated onion seeder. The 10-row onion mechanical seeder had higher field capacity and seeding rate than the existing 2-row (Table 5). With a higher field capacity, the 10-row seeder can plant more area on a daily basis. In a day with six hours of productive time, the use of 10-row onion seeder in the production areas of Nueva Ecija can plant 2.94 ha employing two persons or a labor requirement of 0.87 person-day ha^{-1}. On the other hand, the use of a 2-row onion seeder can plant 1.26 ha employing three persons for planting and one person-animal for labeling and furrowing or 3.17 person-days ha^{-1}.

Similarly, the multi-row onion seeder had higher field capacity in the production areas of Pangasinan (0.37 ha h^{-1}) than manual broadcasting (0.35 ha h^{-1}) (Table 6) while the seeding rate of the machine (4.94 kg ha^{-1}) was significantly lower than that of manual broadcasting (7.68 kg ha^{-1}). As a coping mechanism to offset low seedling emergence which is inherent in directly-seeded onion, high seeding rate is normally practiced by the onion farmers using manual broadcasting in Pangasinan. They later on thin out to prevent overcrowding and the thinned out seedlings are commonly transplanted to other area or sold to other farmers that practice transplanting method (Idago, et al., 2014). However, farmers claimed that thinning out disturb the growth of adjacent seedlings resulted to uneven growth of the crops. Using the 10-row onion seeder, the labor requirement to plant a hectare of onion was lower by 2.37 person-days compared to manual broadcasting method.

Table 5 Comparison of multi-row onion seeder (10-row model) with two-row onion seeder in Nueva Ecija, 2016-2017

Method of direct seeding	Actual field capacity (ha h^{-1})	Seeding rate (kg ha^{-1})	Labor requirement (person-days ha^{-1})
Multi-row onion seeder[1]	0.34	5.51	0.98
2-row seeder[2]	0.21	4.48	3.17
Difference	0.13 *	1.03*	-2.19

Note: Average of 4 replications; * significant at 5% level using t-test; [1] Trailed by handtractor with one operator and labourer; ** [2] Powered by three persons + one person -animal for furrowing.

Table 6 Comparison of multi-row onion seeder with manual broadcasting method in Pangasinan, 2016-2017

Method of direct seeding	Actual field capacity (ha h^{-1})	Seeding rate (kg ha^{-1})	Labor requirement (person-days ha^{-1})
Multi-row onion seeder [1]	0.37	4.94	0.90
Broadcasting[2]	0.35	7.68	3.34
Difference	0.06*	-2.74*	-2.44

Note: Average of 5 replications; * significant at 5% level using t-test; [1] Trailed by handtractor with one operator & one laborer; [2] Powered by two person for sowing +five persons for seed covering.

3.3.2 Seedling survival and number of plants at harvest

As reported by Kyada and Patel (2014), the performance of seeder in terms of the uniformity of seeding depth, distribution of seeds along rows and uniformity of soil cover affect seed emergence. The performance of multi-row onion seeder in terms of onion seedlings that emerged on the 12 and 24 DAFI was comparable with the farmer's practice of using two-row seeder and manual broadcasting (Table 7). The results imply that there would be no significant changes in seedling survival if the 10-row onion seeder is used in place of manual broadcasting and two-row onion seeder.

Table 7 Seedling survival and number of plants at harvest of onion planted by the 10-row onion seeder compared to two-row manual seeder and manual broadcasting method; 2016-2017

Particular	Seedling emergence (% of viable seeds sown)		No. of rows in 10-meter width of plot	Actual No. of plants m^{-2}
	12 DAFI	24 DAFI		
Multi-row versus 2Row seeder				
1. 10-row seeder	59.6	46.2	48	68
2. 2-row seeder	46.4	42.8	38	45
Difference	13.2 ^{ns}	3.4^{ns}	10*	23**
p-value	0.053	0.449	0.011	0.000
Multi-row versus Broadcasting				
1. Multi-row seeder	57.9	49.2	na	78
2. Broadcasting	53.3	42.7	na	79
Difference	4.6 ^{ns}	6.5^{ns}	na	1^{ns}
p-value	0.410	0.294		0.919

Note: na - not available, ns – not significantly different at 5% level of significance.

As shown in Table 7, the difference in plant population between 10-row and 2-row onion seeder was significant (p<0.05) that the plant population was higher in 10-row onion seeder (67 plants m^{-2}) than that in 2-row onion seeder (48 plants m^{-2}). The number of rows planted by the 10-row onion seeder (48 in 10 meter width) was significantly higher than the number of rows planted by the 2-row onion seeder (38 in 10 meter width of plot). On the other hand, actual number of plants m^{-2} of the 10-row seeder and the manual broadcasting method was comparable at 72 and 76 plants m^{-2}. The actual number of plants m^{-2} in the broadcasting method was taken after thinning out and plants are fully grown and maintained until harvest.

Other than the manner at which the seeds were placed in the soil, seedling survival was observed to be affected by the manner of land preparation and crop management pattern (e.g. irrigation, weeding, fertilizer and pesticide application). Well-prepared land was observed to have higher seedling survival. Likewise, the initial irrigation after planting and the occurrence of weeds during the seedling stage seemed to affect seedling survival. Seedbed or plot area flooded during initial irrigation was observed to have lesser percent seedling emergence. The early presence of weeds also affected seedling performance as weeds grew faster and overcrowded or hindered the emergence of seedlings. It is important to note that the percent of seedling survival tends to decrease from 12 to 24 DAFI, suggesting that other factors like soil and occurrence of early pests exert influence on seedling survival.

4 Conclusion and recommendations

The present seeding operations incur high cost and register low yields. A mechanical seeder, a multi-row, tractor-trailed and drill type planter, was designed and developed to increase onion yield and reduce production cost. The seeder is capable of opening a furrow, metering the seed, delivering the seed to the furrow, covering the seed and firming the seedbed. The study evaluated the 10-row onion seeder. It attained an average planting capacity and field efficiency of 0.41 ha h^{-1} and 77.23%, respectively. The field efficiency of the machine passed the standard set by PAES which is 60%. The application for patent of the machine developed was accepted by the Intellectual Property Office-Philippines in 2017.

The time required to complete planting operation and the labor requirement to plant a hectare of onion were shown to be substantially lower with the use of the 10-row onion seeder. The seedling survival of bulb onion planted by the 10-row onion seeder was comparable with the bulb onion planted by 2-row seeder and manual broadcasting method. The use of 10-row onion seeder could significantly increase the plant population in production areas where 2-row onion seeder is used while it could substantially reduce the quantity of seeds used in production areas where manual broadcasting method is being practiced without significantly reducing plant population at harvest.

A more extensive pilot testing of the technology was recommended to quantify the financial benefits of using the technology.

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