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Design and Development of Wooden Plate Metering Device for Onion Bulb Planter

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Abstract

An inclined plate metering device for onion bulb planter was developed and its performance was evaluated in CAE, Lab, JNKVV, Jabalpur. Elevating error, cell fills, bulb damage, actual planting distance, mean planting distance, planting error and feed index were evaluated under the different peripheral speed of the rotor with respect to 3 angular positions of metering plate. It was found that elevating error was minimum (1.51 %) at the metering plate inclination of 50° compared to 60° and 70° at the peripheral speed of 7.6 m/min. The cell fill was maximum (100.38 %) due to double feed at the inclination angle of 50° compared to 60° and 70° at the peripheral speed of 7.6 m/min but the bulb damage was found nil at the inclination angle 50^0 at a peripheral speed 7.6 m/min. The bulb damage increases with an increase in peripheral speed of the rotor and actual planting distance, mean planting distance, planting error was minimum 10.79 cm, 11.08 cm, 1.92 cm respectively, with a maximum feed index of (93.17%) at minimum travel speed 0.6 km/h. However, the actual planting distance, mean planting distance, planting error increased and feed index decreased with the increase in travel speed, but the cell fill decreased with the increase in peripheral speed at all inclination positions.

Keywords: Bulb, elevating error, cell fill, bulb damage, planting distance

In India Onion (*Allium cepa* L.,) is an important commercial vegetable crop mainly used for local consumptions as well as for export purpose. However, planting onion bulbs are beneficial because onion seeds obtained from this can grow in a wide range of agro-climatic condition. India is the second largest producer of onion in the world next after China. In India onion is cultivated in an area of 1203.590 hectares with an annual production of 19401.690 MT with an average productivity of 16.12 tons/ha

(ICAR 2013- 2014). In India onion is grown in three cropping seasons, namely, *Kharif* (harvested in October-November), late *Kharif* (January-February) and *Rabi* (April –May). However, the *Rabi* season crop accounts for about 60 % of annual production while *Kharif* and late *Kharif* each account about 20% Maharashtra, Karnataka, Madhya Pradesh, Andhra Pradesh, Bihar, Gujarat, Rajasthan, and Haryana are the major onion producing states of India. Maharashtra is the largest producer of onion in India, grown in an area of 468.00 hectares, contributing 29% of market share. However, the main constraint to increasing the productivity, crop quality is due to inadequacies in varieties, seed quality and inefficient methods of applying inputs like fertilizers, pesticides etc., (Rajan and Sirohi, 2006).

At present, there are two methods of onion seed production, seed to seed and bulbs to seed. However, bulb to seed method is the most widely followed method for seed production. In the bulb to seed method, the bulbs produced in the previous season are harvested, selected, stored and replanted to produce seeds in the second year. Mostly the bulb to seed method is followed for seed production because it permits selections of 'true-to-type' and healthy bulbs for seed production and seed yields are comparatively very high. During onion cultivation, transplanting of seedlings, weeding and harvesting are labour and time intensive operations that are presently done manually in India. The labour requirement in the manual transplanting of onion seedlings is as high as 100-120 man-day/ha as 8.9 lakhs seedlings per ha are to be transplanted (Rathinakumari *et al.,* 2003). However, onion can also be cultivated by direct placement of onion bulb which is an emerging technology which can be beneficial in terms of labours, time and economy. Considering the above statement, an inclined plate metering device was designed and developed for onion bulb planter having an onion bulb usually less than 35 mm in diameter to overcome the problems like cutting, crushing, elevating, damaging and choking that were observed in another metering mechanism.

Materials and Methods

Design Consideration

The metering device was designed and developed in such a way that it should be capable of performing precision planting which implies accurate placement of individual seed in a row at equal spaces between seeds. The seed should deliver into the seed tube at a time and it should not never be damaged during metering and should deliver the seed effectively. It also should not be affected by the variation of seed quantity in the seed box to an extent for a very small quantity of seeds. To full fill, these requirements, design of a cell type metering device was conceived. To meet the above design consideration a lightweight circular wooden plate having 8 numbers of U- shaped cell was made in the periphery of the metering device to deliver the onion bulb less than 35 mm diameter easily.

Design and fabrication of seed box

The seed box of the planter was designed by using Autodesk inventor 2012 as shown in fig. 1. The seed box should have enough capacity to carry the sufficient quantity of seed, the weight of the material and field efficiency are important factors for deciding the capacity of the seed box as it affects the performance of the planter. The Angle of inclination of seed box, it's an important consideration to allow easy movement of onion bulb towards the metering plate and should be kept greater than the maximum angle of repose but less than 60˚.

Calculation of seed box volume

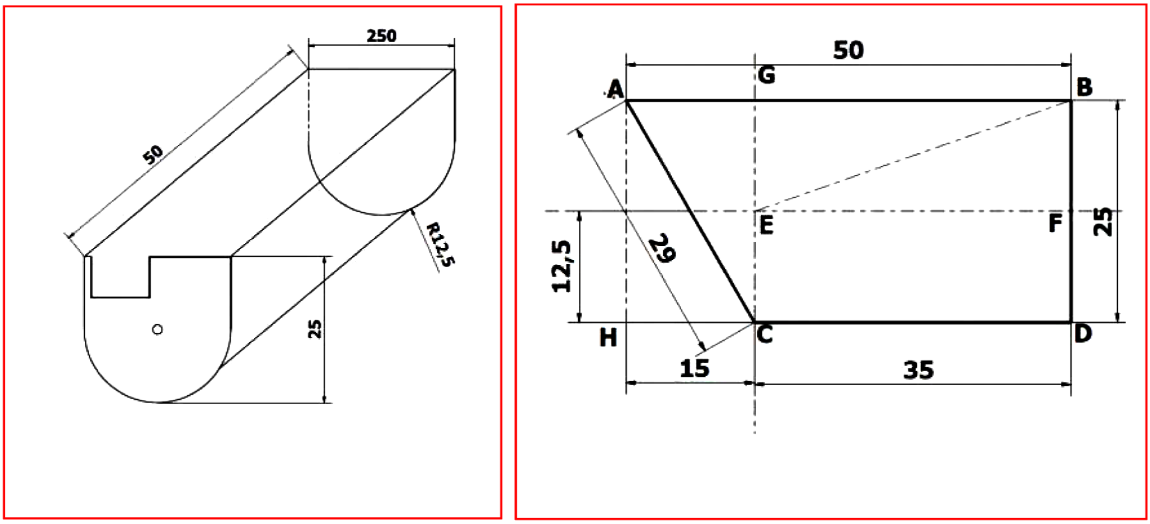

Fig. 1: Geometry of seed box

From the geometry of the seed box as shown in fig. 1, we calculated the volume of the seed box.

Volume of semicircular portion (ECDF) = $\frac{1}{2}\pi r^2 l$ … eq (1)

Half volume of the rectangular portion (GBEF) = $(l \times w \times h)/2$ … eq (2)

Where,

r = radius (0.125 m);

l = length of the seed box (0.35 m);

h = height of the seed box (0.25 m) and;

w = width of the seed box $w = 2r$

Volume of semicircular portion = $\frac{1}{2}\pi r^2 l$ … eq (3)

$$= \frac{1}{2} \times 3.14 \times 0.125 \times 0.125 \times 0.35 = 0.0085 \text{ m}^3$$

Volume of rectangular part = $(l \times w \times h)/2 = (0.35 \times 0.25 \times 0.125)/2 = 0.0054 \text{ m}^3$

Total theoretical volume of seed box =

(Volume of semicircular portion) + (Half volume of rectangular portion)

$= 0.014 \text{ m}^3$

The actual volume of seed box which will be used to fill onion 70 %) $= 0.014 \times 0.70 = 0.01 \text{ m}^3$

Capacity of seed box

= Actual volume of seed box, m^3 × bulk density, kg/m^3

= 0.01 × 566 = 5.6 kg

To meet the above design consideration, a 2 mm M.S. Flat sheet was selected for the fabrication of seed box and it was folded in U-shape. Opening of 100×70 mm was provided to discharge the onion bulb to the seed delivery tube. Overall dimension of seed box was 500×552× 250 mm as shown in fig. 2. On the basis of above design consideration and design parameter the seed box was fabricated for the experimental purpose.

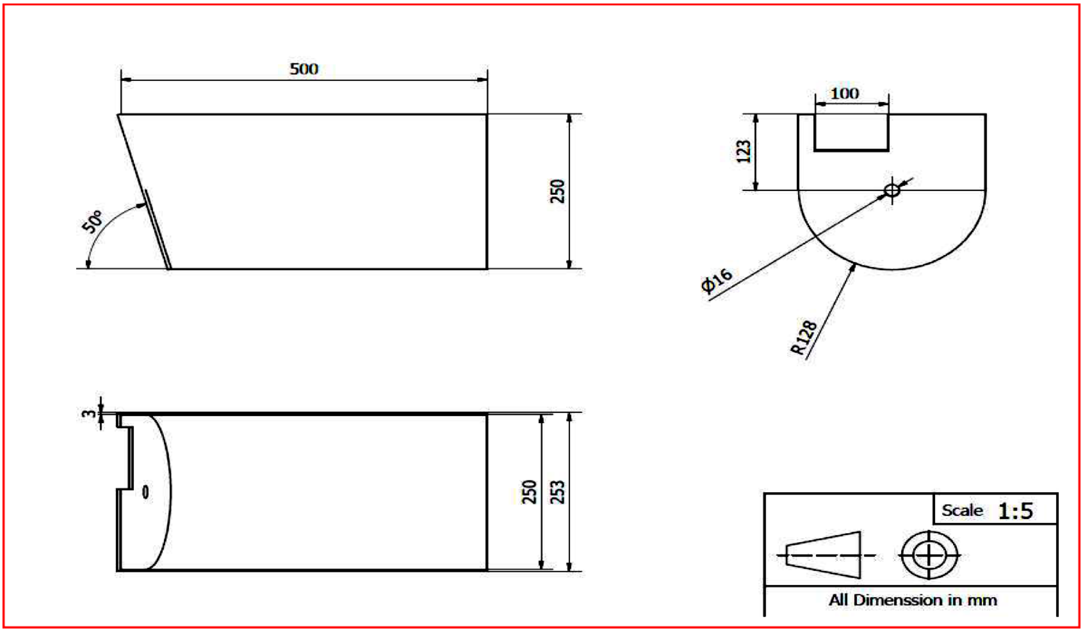

Fig. 2: Orthographic view of seed box hopper

Design and fabrication of metering plate

Calculation of number of cells on metering device

The numbers of cell are calculated by using the formula as shown in below

$$I = (c \times t)/a \quad \text{… eq (4)}$$

I = No. of cells on the metering device;

c = circumference of drive wheel, cm;

t = speed ratio (drive wheel shaft to metering shaft);

a = bulb to bulb spacing = 10 cm, (Craig, 1995)

Speed ratio from drive wheel shaft to metering shaft = (No. of teeth on metering shaft (T_M)/ No. of teeth on drive wheel shaft (T_D),

$$\frac{N_D}{N_M} = \frac{T_M}{T_D} \quad \text{... eq (5)}$$

$$= \frac{16}{24} = 0.66$$

Circumference of drive wheel = π × d = 3.14 × 39 = 122.46 cm

i = (c × t)/a = (122.46 × 0.66) /10 = 8.08

Number of cells was taken = 8

Circumference of metering plate = π × d = 3.14 × 25

= 78.5 cm

Distance between cell to cell = circumference of metering device / No. of cups

= 78.5 /8 = 9.8 cm

Therefore, distance between cell to cell was taken as 10 cm

A light weight circular wooden plate was used for metering device where 8 numbers of U- shaped cell was cut as shown in figure 3 & 4. The size of the cell was made 38 mm width and 40 mm depth on 250 mm diameter wooden having thickness of 30 mm. A hole of diameter 16 mm was provided at the centre of the metering plate for rotating the metering plate. Speed ratio of 0.66 was taken to maintain 10 cm plants to plant spacing the travel speed was assumed between 0.5 to 3 km/h, on the basis of assumption the metering plate was designed and fabricated.

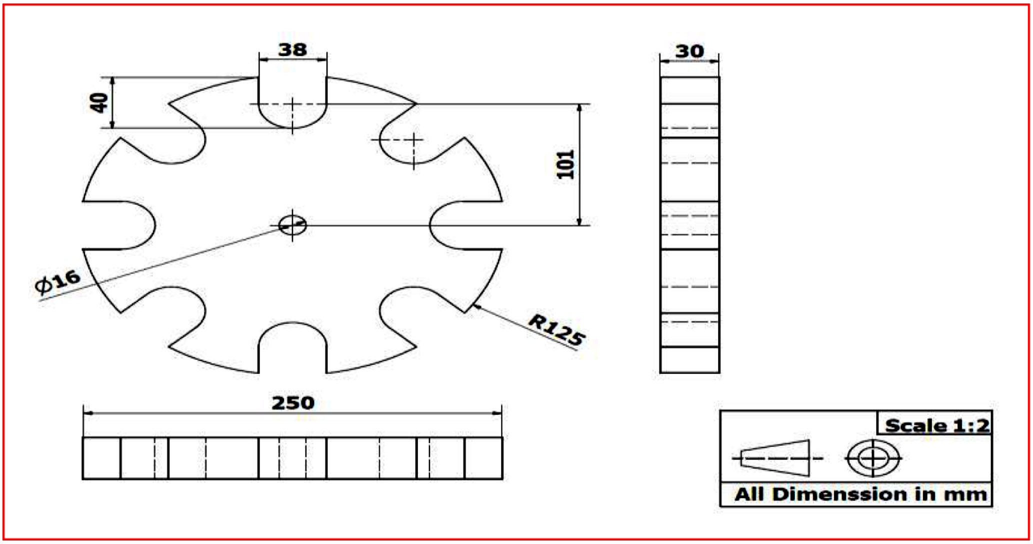

Fig. 3: Orthographic view of metering plate

Fig. 4: Pictorial view of metering plate

Design and fabrication of metering shaft

Since it was not possible to predict the load on the metering shaft in terms of hp transmitted and the speed of rotation, N_s. Empirical formula was adopted for the design of the shaft (Patel, (2012). Metering shaft received power from drive wheel, i.e. ground wheel with speed ratio of 0.66. Empirical formula used here is (Patel, 2012)

$$d = \sqrt[3]{\frac{hp \times C}{N_s}}$$

Where,

d = diameter of the metering shaft in, cm;

C = constant with a value of 810 for transmission shafts subjected to torsion only;

N_s = Speed of metering shaft, rpm;

Assumptions for the design,

hp to be transmitted = 0.033 (hp assumed is 1/3 of the average hp of the healthy person)

N_s of the shaft = 22 rpm is equal to 1 km/h

$$d = \sqrt[3]{\frac{0.033 \times 810}{22 \times 0.65}} = 1.23 \text{ cm}$$

Therefore, the diameter of the shaft was taken 16 mm.

On the basis of above, the M.S. rod shaft of 16 mm diameter and 260 mm length was prepared on the lathe. Metric thread of 16 mm length and 2 mm pitch was made at the one end of the shaft.

Design considerations and fabrication of seed delivery tube

Seeds should fall freely from the metering device through the conical funnel into the tube in the furrow. Uniform seed to seed spacing is achieved when all the seeds are released by the metering device from the same height with the same velocity. The tube should be smooth and the diameter should be sufficient to facilitate smooth flow of seed without clogging and damaging.

To meet the design consideration, the seed delivery tube in which diameter of seed tube upper conical portion is 120 mm and the, lower conical portion is 50 mm with overall height is 300 mm was fabricated.

Power transmission

A positive drive was provided to the seed metering device to ensure minimum power loss and to maintain metering accuracy. A multi-stage transmission sprocket was used and the successive variations in the number of revolutions should be as small as possible. Two chain sprockets with five stages were used to have different peripheral speeds of metering device. The speed ratio was calculated from drive wheel to metering mechanism as shown in equation (5). Table 1 shows the speed ratio obtained without and idler. The pictorial view the developed planter is shown in fig. 5.

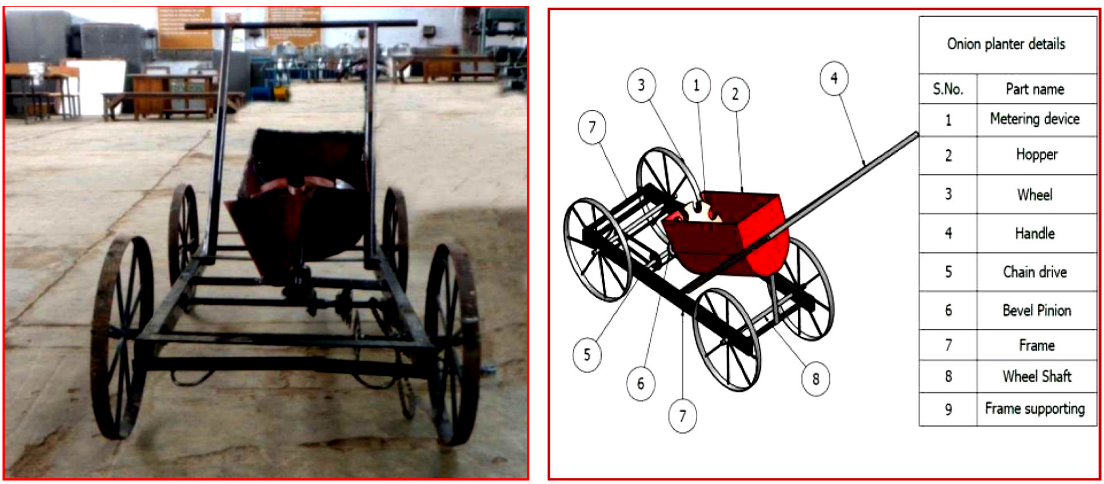

Fig. 5: Pictorial view of Onion bulb planter (Experimental set-up)

Table 1: Speed ratios obtained with a chain without idler

Sl. No.	No. of teeth on metering shaft (T_M)	No. of teeth on drive wheel shaft (T_D)	Speed ratio ($N_D/N_M = T_M/T_D$)
1	28	14	0.5
2	24	16	0.66
3	20	20	1
4	16	24	1.5
5	14	28	2

Indices

Elevating error

Elevating error is the ratio of the number of empty and double fed cups passed per min to total number of cups passed per min (IS: 9856-1981).

$$\text{E.E.} = \frac{\text{No. of empty and double fed cups passed per min}}{\text{Total No. of cups passed per min}} \times 100$$

Bulb damage

The number of bulbs discharged in 10 complete revolutions of ground wheel from seed tube, were collected and observed. The number of bulbs that were damaged mechanically, including any significant bruising, skin removal or crushing was counted and their percentage was calculated as the seed damage percentage (Bakhtiari and Loghavi, 2009).

$$\text{Cell fill \%} = \frac{\text{No. of bulblets dropped}}{\text{Number of cell passed}} \times 100$$

Cell fill percentage

Metering plate performance was measured in terms of cell fill percentage. It is the ratio of the number of seeds collected and number of cells passed at a particular distance in the row, (Singh *et al.,* 2006) expressed asunder:

Mean planting distance

Mean value of planting distances measured with missed and accumulated tubers.

Actual planting distance

The mean value of planting distances measured without missed and accumulated tubers (IS: 9856-1981).

Planting errors

This is defined as the deviation from desired equal tuber distribution in a row. (IS: 9856-1981).

Quality of feed index

The quality of feed index is the percentage of spacing without missed and accumulated distances. The quality of feed index is an alternate way of presenting the performance of misses and accumulations.

$$\text{QFI} = 100 - \left(\text{Misses}(\%) + \text{Accumulation}(\%)\right)$$

Misses

The number of planting distances which are equal or more than twice of the rated planting distance. (IS: 9856-1981).

Accumulations

The number of planting distances which are equal or less than one-third of the rated planting distance. (IS: 9856-1981).

Results and Discussion

Development of main components

The developed planter with inclined metering plate worked satisfactorily during the test. The metering plate carried the onion bulbs from the seed box and delivered properly it the seed tube. As the onion level was maintained above the lowermost portion of cell therefore, the cell was filled during rotation of the plate and the power from drive wheel to the metering device was also transmitted smoothly.

Performance evaluation of developed metering plate in laboratory

Effect of the peripheral speed of metering plate on an elevating error at an inclination angle of 50°, 60° and 70°

The elevating error was found minimum 1.51 % and maximum 10.82 % at peripheral speed of 7.6 to 45.59 m/min at an inclination of 50°. At 60° inclination, elevating error was minimum 2.66 % and maximum 11.83 % at peripheral speed of 7.6 to 45.59 m/min. Similarly, at an inclination of 70° the elevating error was minimum 4.95 % and maximum 15.48 % at peripheral speed of 7.6 to 45.59 m/min. The number of cells, empty cell and double fed cell per minute passed with respect to peripheral speed is shown in table 2. In all the three cases elevating error increases with an increase in peripheral speed and the increase in elevating error was due to increase in empty cells as the peripheral speed increased. Fig. 6 shows the comparison of three inclination angle on elevating errors.

Effect of the peripheral speed of the metering plate on cell fills at an inclination angle of 50°, 60° and 70°

The cell fill was maximum 100.38 % and minimum 88.98 % at peripheral speed of 7.6 m/min and 45.59 m/min at an inclination of 50^0. At an inclination of 60^0 cell fill was maximum 98.85 % and minimum 87.03 % at peripheral speed of 7.6 m/min and 45.59 m/min. Similarly, the cell fill was maximum 96.18 % and minimum 84.44 at peripheral speed of 7.6 m/min and 45.59 m/min an inclination of 70°. In all the three cases as the peripheral speed increases the cell fill tends to decrease and decrease in cell fills % with an increase in peripheral speed was due to increase in empty cells. Fig. 7 shows the comparison of cell fills at three inclination angles of the metering plate at different peripheral speed m/min.

Effect of travel speed on actual planting distance, mean planting distance, planting error, and feed index under laboratory condition

It was found that as the travel speed increased actual planting distance increased and the actual planting distance of 10.79 cm was found minimum which is close to rated planting distance, i.e. 10 cm, at travel speed of 0.6 km/h but, actual planting distance was maximum 12.72 cm at travel speed 2.3 km/h also actual planting distance increases as misses and accumulations increased with speed. As the travel speed increases mean planting distance also increased and at the speed of 0.6 km/h mean planting distance of 11.08 cm was minimum which is close to rated planting distance, i.e. 10 cm but maximum of 13.77 cm at travel speed 2.3 km/h. Planting error increases with the increase in travel speed and in travel speed of 0.6 km/h planting error was minimum 1.92 cm but was maximum 4.62 cm at travel speed of 2.3 km/h. It was found that as the travel speed increases feed index decreased and maximum feed index of 93.17 % was obtained at the speed of 0.6 km/h and minimum of 73.01 % at 2.3 km/h. Feed index decreased with the increases in travel speed, as misses and accumulations increased with the increase in travel speed. Table 2 shows the effect of travel speed on seeding uniformity under laboratory condition.

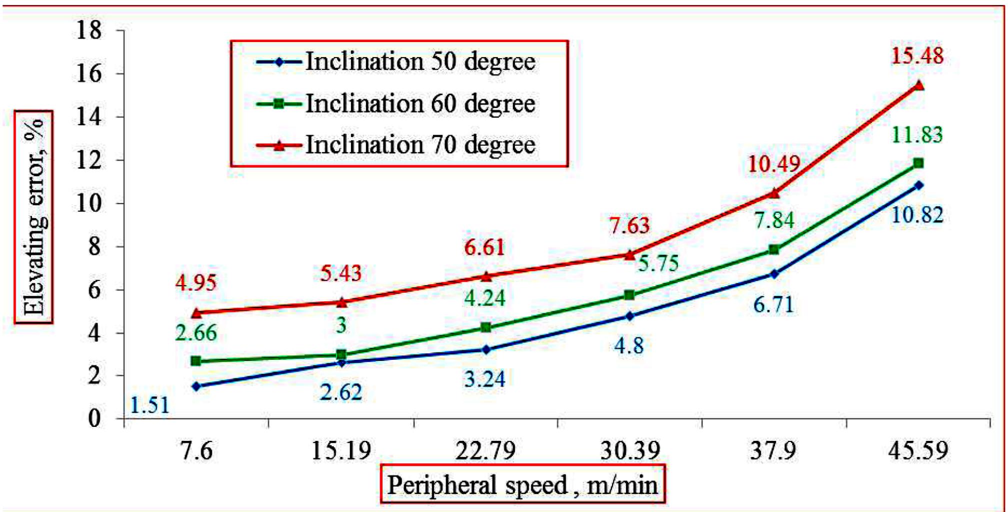

Fig. 6: Comparison of elevating error at three inclination angle of the metering plate at different peripheral speed, m/min

Table 2: Effect of travel speed on seeding uniformity under laboratory condition

Speed (km/h)	Planting distance, (cm)		SD	Variance (%)	Accumulation (no.)	Misses (no.)	Bulb Discharged (no.)	Feed Index (%)	Planting Error (cm)
	Actual	Mean							
0.6	10.79	11.08	3.01	27.16	3	2	73	93.17	1.92
1.2	11.12	11.78	3.50	29.71	5	4	*71*	87.33	2.67
1.9	12.42	12.85	3.69	28.72	4	9	67	80.59	3.84
2.3	12.72	13.77	4.90	35.58	6	11	63	73.01	4.62

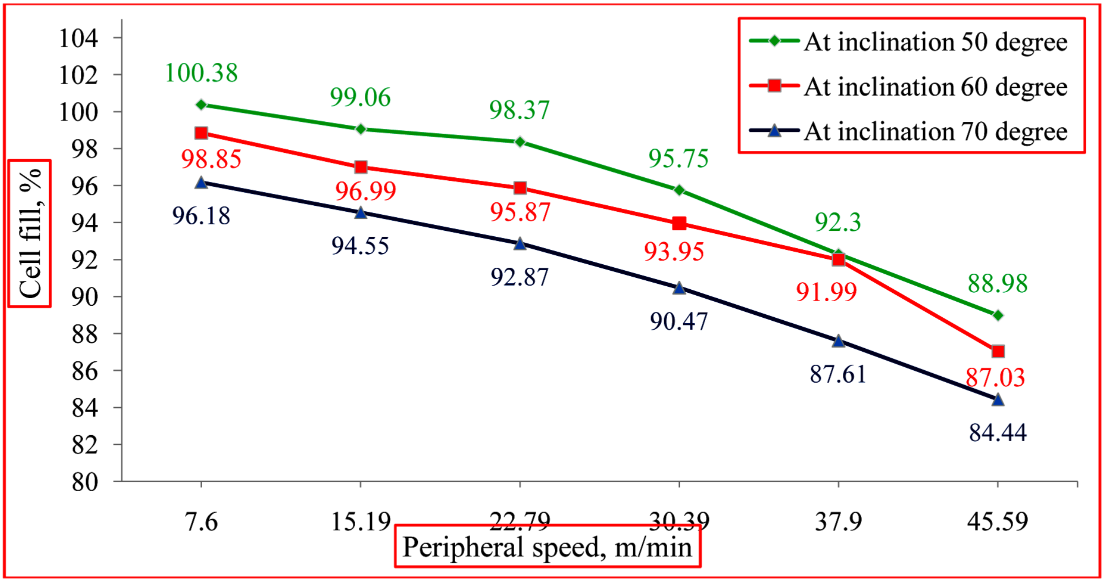

Fig. 7: Comparison of cell fills at three inclination angles of the metering plate at different peripheral speed, m/min

Further Research and Development

Manually operated onion planter can be further designed and evaluated under laboratory condition using the vertical plate metering device and can be further evaluated under field condition to find the actual effectiveness.

Conclusion

The developed metering plate was rotating smoothly in the seed box carrying onion bulbs and it was delivered to the seed tube properly. It is also found that the mean planting distance, actual planting distance and planting error increased with the increase in travel speed, but the feed index decreased with the increase in travel speed as misses and accumulations increased. The elevating error increased with an increase in peripheral speed at all inclination angles at the same time cell fill decreased with an increase in peripheral speed at all inclination angles and the bulb damage was found nil at the inclination angle 50° at peripheral speed 7.6 m/min however, it increases with an increase in peripheral speed. Thus, performance of metering device was best at travel speed of 0.6 km/h.

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References

Adisa, A.F. and Braide, F.G. 2012. Design and development of template row planter. *Transnational Journal of Science and Technology*, **2**(7): 27–33.

Asaduzzaman, M., Hasan, M.M., Hasan, M., Moniruzzaman, M. and Howlader, M.H.K. 2012. Effect of bulb size and plant spacing on seed production of onion (*Allium cepa* L.). *Bangladesh Journal of Agricultural Research,* **37(3): 405–414.**

Asaduzzaman, M., Hasan, M.M., Hasan, M., Moniruzzaman, M. and Howlader, M.H.K. 2012. Effect of bulb size and plant spacing on seed production of onion (*Allium cepa* L.). *Bangladesh Journal of Agricultural Research*, **37**(3): 405–414.

Bakhtiari, M.R. and Loghavi, M. 2009. Development and evaluation of an innovative garlic clove precision planter. *Journal of Agricultural Sciences and Technology,* **11**: 125–136.

Benjaphragairat, J., Sakurai, H. and Ito, N. 2010. Design and control of metering system and furrow openers for garlic planter. *International Agricultural Engineering Journal,* **19**(2): 39–45.

Celik, A., Ozturk, I. and Way, T.R. 2007. Effects of various planters on emergence and seed distribution uniformity of Sunflower. *Transactions of the American Society of Agricultural and Biological Engineers*, **23**(1): 57–61.

Craig, R.A. 1995. Home gardening series of onions. Agricultural and Natural Resources. University of Arkansas, United States Department of Agriculture and County Governments Cooperating.

Dubey, A.K. 2003. Design of sowing machine. Teaching material for training on computer aided design and methodology for agricultural machinery. CIAE/AMD/2003/303: 141–151.

Goswami, M.D. 2001. A laboratory set-up for testing planters and seed-drills. *Journal of Agricultural Engineering*, **38**(4): 69–72.

IS: 6313-1971, Test code for seed-cum-fertilizer drill. BIS, New Delhi.

IS: 9856-1981, Test code for potato planter. BIS, New Delhi.

Madan, P.A. 2013. Development of metering device for onion (*allium cepa L.*) bulblet planter. Unpublished M. Tech. Thesis. Department of Farm Machinery and Power Engineering. College of Agricultural Engineering, JNKVV Jabalpur.

Patel, B.S. 2012. Development of metering device for onion bulblet planter. Unpublished M. Tech. Thesis. Department of Farm Machinery and Power Engineering. College of Agricultural Engineering, JNKVV Jabalpur.

Rajan, P. and Sirohi, N.P.S. 2006. Studies on pneumatic metering of cabbage seeds. Power mach sys erg safety and health.

Raspinder, G.S., Rohinish, K., Manes, G.S., Anoop, D. and Aseem, V. 2015. Development and evaluation of tractor operated inclined plate metering device for onion seed planting. *Agric Eng Int: CIGR Journal,* **17**(2): 31–38.

Rathinakumari, A.C., Mandhar, S.C. and Gowda. R.V. 2003. International seminar on Downsizing Technology for Rural Development. Development of drum seeder for onion, ISDTRD, Bhubaneshwar, 2003.

Singh, V.C., Shrivastava, A.K. and Dubey, A. 2006. Feasibility evaluation of manual garlic planter. Annual report of FIM scheme, CAE, JNKVV, Jabalpur, pp. 1–12.

Staggenborg, S.A., Taylor, R.K. and Maddux, L.D. 2004. Effect of planter speed and seed firmers on corn stand establishment. *Transactions of the American Society of Agricultural Engineers*, **20**(5): 573−580.

Stoffella, P.J. 1996. Planting arrangement and density of transplants influence sweet Spanish onion yields and bulb size. *Hortscience,* **31**(7): 1129–1130.