The Ecoscan 11(1&2): 037-043, 2017
AN INTERNATIONAL QUARTERLY JOURNAL OF ENVIRONMENTAL SCIENCES
www.theecoscan.com

DESIGN AND FIELD EXPERIMENTS OF PRECISE SEED METERING MECHANISM WITH PADDY SEEDS IN CHHATTISGARH

MANISHA SAHU* AND AJAY VERMA
Department of Farm Machinery and Power Engineering,
SV College of Agricultural Engineering and Technology& Research Station, IGKV, Raipur - 492 012, INDIA
e-mail: sahumanisha79@gmail.com

ABSTRACT

An experiment was conducted in SVCAET&RS, FAE, IGAU, Raipur with a view to design and simulation of inclined metering mechanism with lab set-up device for paddy seeds in solid-works software. Inclined metering mechanism was tested for different forward speed of planter, different inclination angle and different rotor speed of metering plate in laboratory and field. The seed rate was found 13.35 kg/ha, 17.26 kg/ha and 26.39 kg/h for seed spacing of 20, 15 and 10 cm, respectively at 4.5 km/h forward speed and 45º inclination angle of metering plate and each cell picked two to three seeds of paddy. Minimum seed damage (0.28%) was observed at 45º inclination angle of metering plate and 4.5 km/h forward speed of planter.

KEY WORDS
Direct seeding
Inclined plate planter
Paddy
Solid-works

Received : 00.00.2016
Revised : 00.00.2017
Accepted : 00.00.2017

*Corresponding author

INTRODUCTION

Conventional seeding devices have higher seed rate hence increases the production cost. In the future and when the planting densities exceed the optimum level, competition among plants becomes severe and consequently the plant growth slows and the grain yield decreases (Chaudhary *et al.,* 2015). It is, therefore necessary to determine the optimum density of plant population per unit area for obtaining maximum yield. Wider spacing had linearly increasing effect on the performance of individual plants (Dwivedi *et al.,* 2015). Using inclined plate planter, seed germination efficiency has increased manifolds at reduced seed rate as compared to conventional planters. Planting equipments with inclined plate seed metering devices are used in India and many developing countries for planting of peanut (Arachis hypogaea), chickpea (Cicer arietinum), pigeon pea (Cajanus cajan) and maize (Zea manys) crops. Inclined plate seed metering device (Figure 1) consists of a metering plate with cells on its periphery to carry two to three seeds in each cell at appropriate time from hopper to the furrow through a seed tube. The metering plate is kept inclined at 60° to the horizontal (Sahoo and Shrivastava, 2000; Kamble *et al.*, 2003). The drive for the rotation of metering plate is given from ground wheel of the planter. As the power source drives the planter in field, metering plate rotates and pick up the seed in its cell against the pull of gravity. The seed fall out of the cell due to non-availability support from the base plate and gets dropped by gravity in a row at more or less uniform spacing.

Seed is metered in precision planters, accuracy of seed to seed distance in a row, called seed spacing (Korayem *et al.,* 1986; Kachman and Smith, 1995) and number of seeds dropped per unit area, called seed rate (Heege, 1993) are most performance parameters. Theoretically, they are determined as follows:

$$\text{seed spacing} = \frac{\text{forward speed}}{\text{(number of cells on the metering place x rotary speed of metering place}} \quad (1)$$

$$\text{Seed rate} = \frac{\text{number of cells on the metering place} \times \text{rotary speed of metering place}}{\text{row spacing} \times \text{forward speed}} \quad (2)$$

The above equation (2) assume that, each cell always pick up two seeds from the hopper and drop it into the seed tube during operation, i.e., percent cell fill of 100. However, under actual field conditions, cell may fail to pick up any seed or cell may pick up and drop more than one seed at a point or seed may not emerge from soil due to damage of seed during metering (Kachman and Smith, 1995; Singh *et al.*, 2005) thereby leading to variation in seed spacing, seed rate and plant population (number of plants/unit area). In order to achieve the uniformity in seed spacing and accuracy in seed rate, it is essential to use the metering plate with size of cells matching to the size of seeds (Jayan and kumar, 2004; Korayem *et al.,* 1986). Further, size of cell coupled with speed of rotation of the metering plate significantly affects cell fill and seed damage (Singh *et al.*, 2005; Barut and Ozmerzi, 2004; Santos *et al.*, 2003). Hence, it is essential in a planting equipment with inclined plate seed metering device to first select a metering plate of suitable cell size and operate it at the rotary speed that shall result in 100% cell fill and minimum seed damage, and then adjust the forward speed of the planting equipment to obtain the recommended seed rate and seed spacing. This necessitates the development of highly accurate models for the seed rate, seed spacing and percent seed damage based on the independent design and operational parameters like, size of seed, forward speed of planting equipment, rotary speed of the metering plate and size of cell on the plate. Based on the models, the values of design and operational parameters for achieving the 100% fill of the cells along with desired seed rate and seed spacing can be obtained using suitable optimization techniques.

Pro/Engineering software design and deduces the development cost by using virtual space instead of the physical space to improve the accuracy and efficiency of the precision planter (Rui *et al.*, 2006). Deqiu *et al.* (2010) designed and developed a four row potato planter using a feature-based parametric modeling solid-works software. It adopted cross getting seeds and equipped with vibrating ejecting seed parts, it can come to precision planting and row spacing and individual plant spacing can be adjusted. With this experiment both repeating and leaking planting index are less than 3%. Wu and Bao (2015) designed, modeled and simulated the no-tillage planter using virtual prototype technology in solid-works software. The ridge clearing coulter endpoint track, displacement, velocity and acceleration curve have been obtained through simulation are the same as theoretical analysis. The literature on the ue of various optimization techniques for the determination of design and operational parameters of agricultural machinery are available to a limited extent. Yazgi and Degirmencioglu (2007) use response surface methodology (RSM) to determine the optimum level of vacuum pressure, diameter of the seed holes and peripheral speed of seed plate for the precision planting of cotton seeds. The optimum levels of vacuum pressure and diameter of holes for precision seeding of cotton seeds were found to be 5.5 kPa and 3 mm, respectively. Anantachar *et al.* (2010) used the ANN model to determine the optimum forward speed of planting equipment, peripheral speed of the metering plate and the area of cells on the plate for peanut seeds to obtain the recommended seed rate 33.33 seeds/m^2, seed spacing of 100 mm and percent seed damage of 0.2% with 100% fill of cells. Optimum values were obtained for the peripheral speed and inclination angle of the metering plate for paddy seeds.

In present work, an attempt is made to design and optimize the cell of inclined metering mechanism for paddy seeds and develop a lab test setup in solid-works software to test and evaluate the inclined metering mechanism in virtual space. Moreover, determination set of input parameters (forward speed of the planting equipment, rotary speed of the metering plate and inclination angle of the plate from horizontal plane) for the set of desired outputs (seed rate, seed spacing and percent seed damage) is an important practical requirement. In the present work, an attempt was made to use the solid-works software to generate the optimum values of forward speed of the planting equipment, rotary speed of the metering plate and inclination angle to the horizontal of the plate for achieving the desired seed rate and seed spacing with minimum seed damage. So, the present deals with design and development of inclined metering unit for rice and development of lab set up unit in solid-works for the prediction of performance parameters of an inclined plate seed metering device and to determine the optimum values of design and operational parameters of the seed metering device.

MATERIALS AND METHODS

Optimization of inclined seed metering mechanism in solid-works software

Facing the long-standing problems existing in higher cost of fabrication of development of new product, so the inclined metering unit and lab set-up planter was designed and simulated in solid-works software. The optimum size of cell on the inclined metering plate was decided on the basis of physical dimensions of paddy. The half distance of the minor

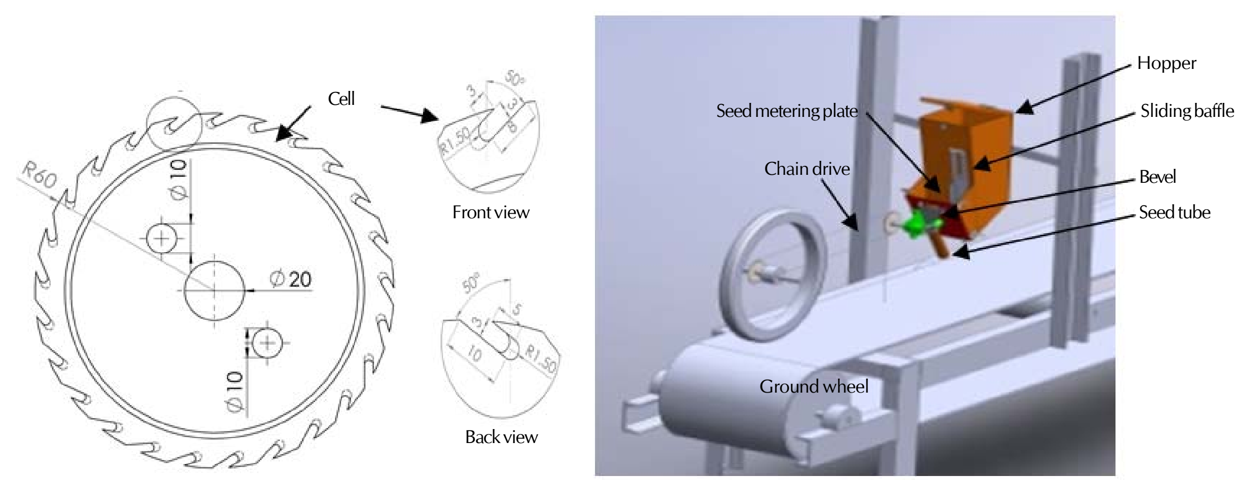

Figure 1: Schematic diagram of inclined plate seed metering device along with lab set-up

axis of the seed plate cell was chosen 10% more than half breadth of the seed by Anantachar *et al*. (2010). Developed edge type cells had 3 mm width, 8 mm and 10 mm length from front and back, respectively on seed metering plate (Figure 1). These dimensions were designed on the basis of accommodation of two seeds per cell. In solid-works software experiments conducted with this inclined metering mechanism having 25 no. of cells rotate at different speed followed by different inclination angle and forward speed (Figure 2). The metering plate was kept inclined at an angle of 60° to 40° with the horizontal by Yadachi *et al.,* [23]; Kamble et al., [9]. Hence, inclined metering plate of lab set-up planter has been inclined horizontally with an angle 50°, 45° and 40°. In India forward speed of tractor mounting planting equipment varies from 2.0 to 5.0 km/h under actual field conditions (Kamble et al., [9].) Keeping this point in mind, three levels of linear speed of lab set-up (forward speed of planting equipment) viz: 2.5, 3.5 and 4.5 km/h were considered for the experiment.

Laboratory evaluation

Performance of the metering plate was evaluated in accordance with RNAM test code and procedures for the laboratory performance test of seeder and planter (RNAM, 1995). A sticky belt test stand along with seed metering device was used for the performance evaluation of metering plate. The length and width of the belt was 5000 mm and 600 mm, respectively. The metering plate was fixed in the seed metering device. Grease was smeared on the rubber belt to retain seed falling on the belt. An electric motor of 5 hp was used to drive the sticky belt and motion was transmitted to the ground wheel, through which motion was transmitted to the inclined metering shaft with the help of belt and pulley arrangement. Variable sets of pulleys were mounted on the axle of the ground wheel and shaft of pinion gear of metering plate to get different desired seed spacing (Figure 3).

Measurement of seed damage

The ground wheel of inclined planter was rotated and seeds were collected on the poly-ethylene sheets underlying the seed tube, seed quantity and numbers of seeds in the collection sheets were measured individually.

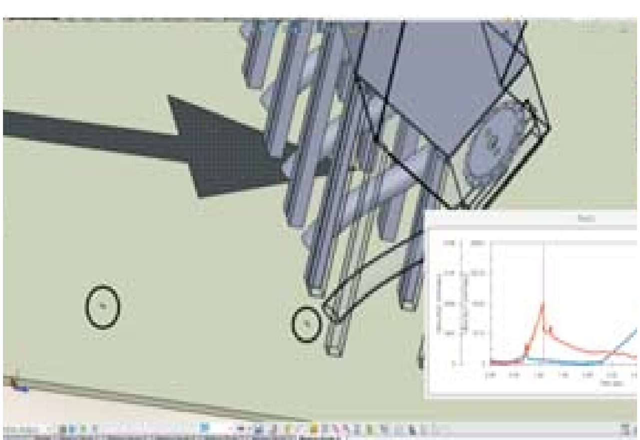

Figure 2: Spacing between two seeds in solid-works calculated with graph

$$SD = \frac{W_d}{W_t} \times 100 \quad \ldots(3)$$

SD refers to percent seed damage, W_d refers to the weight of visible damaged seeds and W_t refers to the total weight of seeds metered.

Performance parameters measured during field evaluation

Speed of operation: The time taken (s) to distance travelled (m) during operation was determined using stopwatch. The forward speed of tractor (km/h) was calculated by following equation.

$$\text{Forward speed of tracctor} = \frac{\text{distance}}{\text{time}} \times 3.6 \quad \ldots(4)$$

Field capacity and field efficiency: The actual field capacity, theoretical field capacity and field efficiency of the planter were calculated as follows.

$$AFC = \frac{A_c}{T_t} \quad \ldots(5)$$

$$TFC = \frac{W \times S}{10} \quad \ldots(6)$$

$$FC = \frac{AFC}{TFC} \times 100 \quad \ldots(7)$$

AFC = actual field capacity (ha/h), TFC = theoretical field capacity (ha/h), Ac = actual area covered (ha), Tt = time taken (h), FC = field efficiency (%), W = width of machine (m), S = forward speed (km/h)

RESULTS AND DISCUSSION

Optimization of inclined seed metering mechanism in solid-works software

In solid-works software dropping of seeds by two continuous cells was dropped at particular peak velocity with respect to particular time (Table 4). The time interval between seeds by two continuous cells and forward speed of lab setup planter is used to calculate the seed spacing of metering mechanism. When the forward speed of lab setup planter becomes 2.5 km/h then for sowing of paddy, at desired seed spacing i.e. 10, 15 and 20 cm, the rotational speed of metering plate displayed 0.10, 0.07 and 0.05 m/s, respectively. Simultaneously, speed of metering plate was 0.14, 0.09, 0.07 m/s and 0.17, 0.14, 0.09 m/s respectively at 3.5 and 4.5 km/h (Table 4). The results were based on theoretical analysis of seed metering plate at given forward speed of planter.

Inclination angle influence the contact force between paddy and seed metering plate. Figure 4, Figure 5 and Figure 6 shows that the inclination angle of metering plate is directly proportional to the contact force and reaction force. The optimum contact force was 10 N an 9 N between paddy and inclined plate and between paddy and cell face, respectively at an inclination angle of 45° for all forward speeds, which gives optimum force to pick two or three seeds per cell by metering plate. Reaction force due to gravity was 8 N at 45° inclination angle (Figure 5).

(a) lab set-up of planter (b) seed box with bevel and pinion gear (c) electric motor with power transmission system

Figure 3: Laboratory evaluation

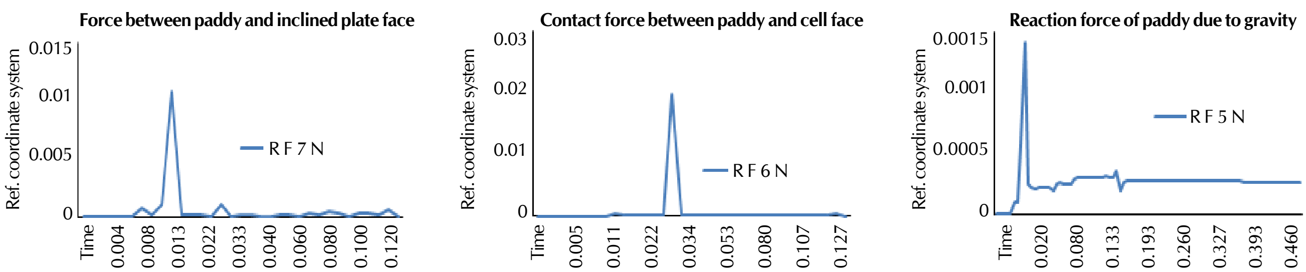

Figure 4: Contact force between paddy and different parts of inclined metering plate at 40° inclination angle and 0.14 m/s of seed plate

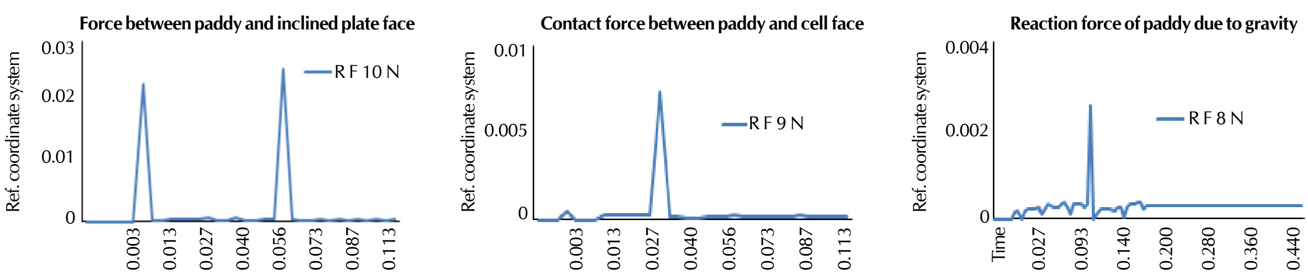

Figure 5: Contact force between paddy and different parts of inclined metering plate at 45° inclination angle and 0.14 m/s of seed plate

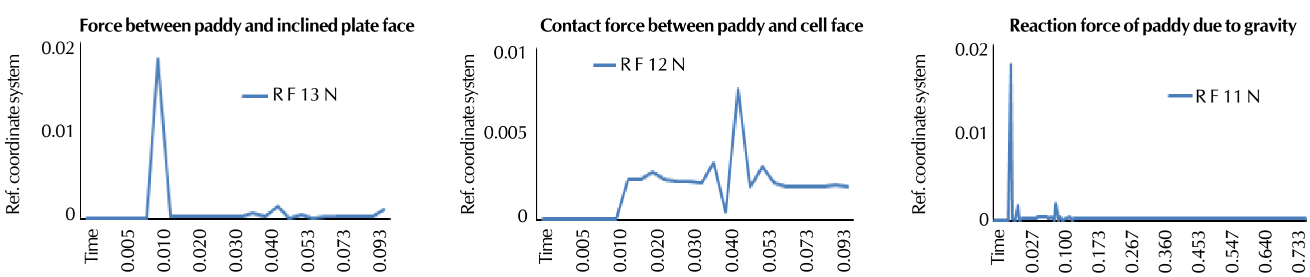

Figure 6: Contact force between paddy and different parts of inclined metering plate at 50° inclination angle and 0.14 m/s of seed plate

Table 1: Physical and engineering properties of the selected five varieties of paddy

Variety	Length (mm)	Width (mm)	Thickness (mm)	Weight of 1000 gm seeds (g)	Geometry mean dia. (mm)	Sphericity (Ø)	Bulk Density (kg/m³)	Angle of repose	Moisture content (%db)
Avg.	9.18	2.54	2.20	26	3.57	0.39	538.86	36.04	15.3
SD	0.142	0.274	0.313	1	0.58	0.297	10.123	0.597	1.301
CV, %	1.19	9.00	10.6	2.56	1.30	1.75	1.44	1.19	5.80

Table 4: Effect of peripheral speed of seed plate on seed spacing with different forward speed of lab setup planter in solid-works

Forward speed, km/h	Rotor speed, (m/s)1	Lab-setup planter speed, cm/s2	Velocity of each seed at the time of dropping, mm/s3	Time, s4	Time interval, s5	Spacing b/n 2 seed, cm6 = 2 × 5
2.5	0.10	69.44	1. 21052. 2119	0.5890.727	0.144	9.99
	0.07	69.44	1. 20482. 2100	0.6690.876	0.216	14.99
	0.05	69.44	1. 21182. 2099	0.7611.040	0.288	19.99
3.5	0.14	97.22	1. 20912. 2131	0.5270.638	0.102	9.91
	0.09	97.22	1. 21032. 2088	0.6070.764	0.154	14.97
	0.07	97.22	1. 20482. 2100	0.6690.876	0.205	19.93
4.5	0.17	125	1. 21372. 2134	0.5140.586	0.09	11.25
	0.14	125	1. 20912. 2072	0.5460.660	0.12	15
	0.09	125	1. 20522. 2122	0.6200.780	0.16	20

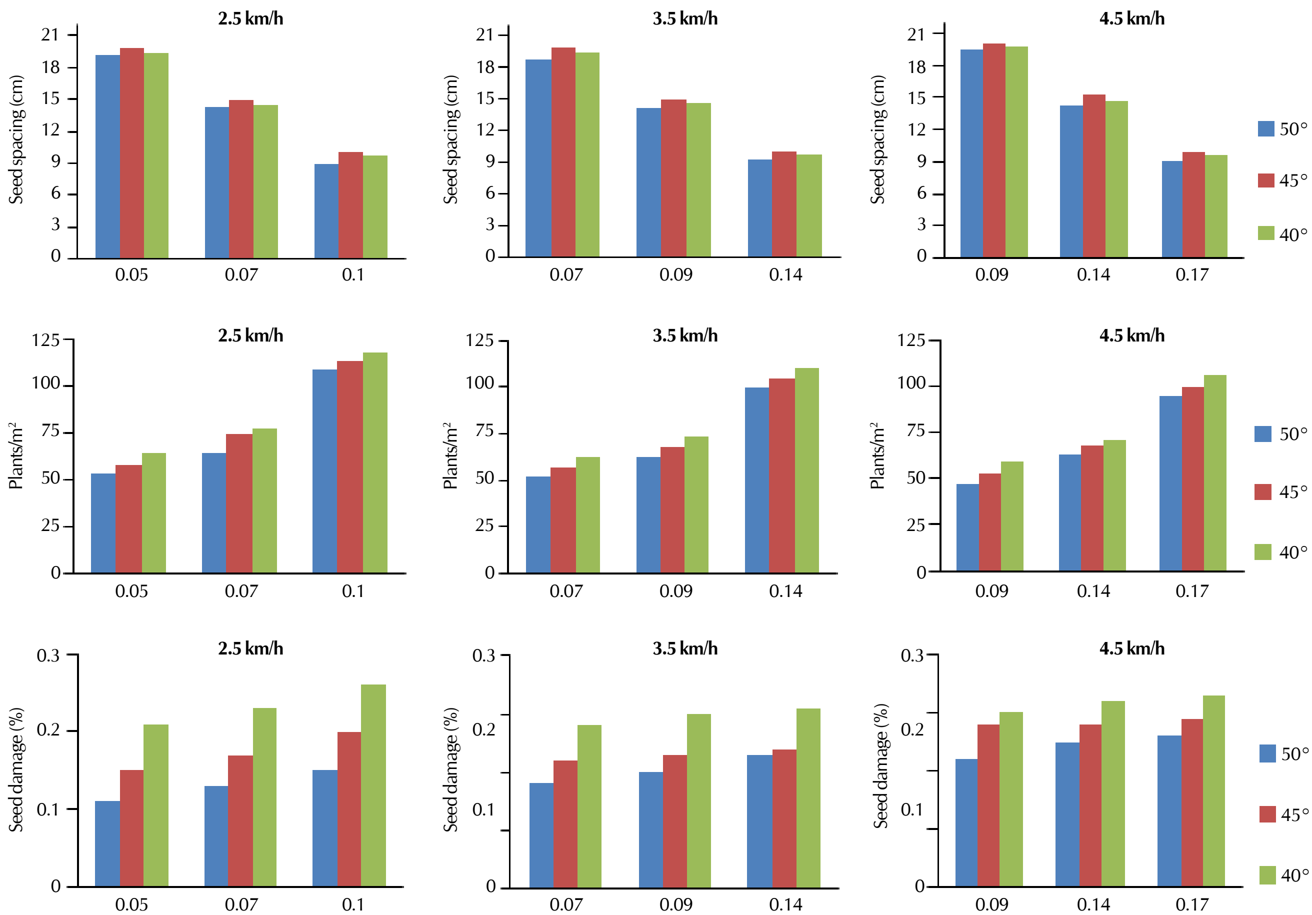

Figure 7: Effect of inclination angle and rotor speed on seed spacing, plants per square meter and seed damage % for different forward speed of the lab setup planter for paddy seeds

Average seed spacing

Average seed spacing was highly influenced by peripheral speed of metering plate followed by inclination angle (Anantachar *et al*. 2010 and Yadachi *et al*. 2013). It was observed that the average seed spacing was inversely proportional to the seed plate speed, which resulted same as in solid works simulation method. When the inclination angle was 45°, average seed spacing was found out to be 20.1, 15 and 10.2 which was nearer to desired seed spacing *i.e.* 20, 15 and 10 cm, respectively and best among the other two inclination angle of metering plate, Figure 7(a).

Seed rate

It was observed that the seed rate was highest, at an inclination angle of 40°,*i.e.* 28.94 Kg/ha followed by maximum peripheral speed of metering plate (0.10 m/s) and minimum forward speed (2.5 km/h) of lab setup planter. This result was found because highly inclined seed plate picks more no. of seeds at minimum forward speed. The optimum seed rate was found to be 13.23 kg/ha, 17.11 kg/ha and 26.25 kg/ha for desired seed spacing of 20 cm, 15 cm and 10cm, respectively at 45° inclination

Figure 8: Field performance of inclined plate planter

angle and higher forward speed (4.5 km/h), Figure 7,b. The peripheral speed of metering plate has the highest influence on the performance parameters of the metering device than that of the other independent parameters Anantachar *et al*. (2010) for peanut seeds.

Laboratory evaluation

The lab set-up planter with sticky belt test was evaluated as per desired seed rate of paddy *i.e*. 13.23 kg/ha, 17.11 kg/ha and 26.25 kg/ha at the seed spacing of 20 cm, 15 cm and 10cm, respectively. In field test seed rate was found as 13.35 kg/ha, 17.26 kg/ha and 26.39 kg/ha at the seed spacing 20 cm, 15 cm and 10 cm, respectively at 45° of inclination angle and 4.5 km/h forward speed.

Seed damage

The maximum seed damage percent was found to be 0.33% at 40° inclination angle at the speed of 0.17 m/s of metering plate because of higher inclination angle and peripheral speed of the metering plate. Seed damage of 0.28% was observed at 45° inclination of metering plate and 4.5 km/h forward speed, Figure 7(c). This is less than the maximum allowable seed damage (0.5%) in a seed metering device of the seed drill and planter (RNAM, 1995). Seed damage in all cases ranged between 0.1 - 0.33 % was low, probably due to the inclination of seed plate.

Field evaluation

The developed inclined metering device was adjusted at 45° of inclination angle and tested on inclined plate planter for all five varieties of paddy at 4.5 km/h forward speed at IGKV university field (Fig.8). The actual field capacity and field efficiency of the inclined plate planter with inclined plate metering device was evaluated in the experimental field by observing actual time requirement and area covered. Before testing the inclined plate planter, the various soil parameters like moisture content, mean mass diameter and bulk density were recorded. The actual and theoretical field capacity for sowing paddy was found to be 0.65 ha/h and 0.77 ha/h, respectively and field efficiencies were calculated as 83.9%. The cost of sowing per hectare with inclined plate planter and conventional fluted roller seed drill was Rs. 485.75 per ha and Rs. 989.75 per ha, respectively. Therefore, it may be said that sowing with tractor drawn inclined plate planter is 2.03 times economical than traditional method. The timely completion of sowing operation as well as enhanced production is an unparallel advantage for the use of planter.

ACKNOWLEDGEMENT

The authors are thankful to the Niche Area of Excellence FMIRA for funding the project, SVCAET & RS, Faculty of Agricultural Engineering, IGKV University, Raipur, for providing the necessary facilities during the research work.

REFERENCES

Anantachara, M. G. V. Kumarb, Prasanna and Guruswamya, T. 2010. Neural network prediction of performance parameters of an inclined plate seed metering device and its reverse mapping for the determination of optimum design and operational parameters. *Computers and Electronics in Agriculture*. **72:** 87-98.

Barut, Z. B. and Ozmerzi, A. 2004. Effect of different operating parameters on seed holding in the single seed metering unit of a pneumatic planter. *Turkish J. Agriculture Forestry*. **28:** 435-441.

Chaudhari, D. R., Patel, A. P., Patel, V. P., Desai, L. J., Patel, J. V. and Tandel, D. H. 2015. Effect of age of seedlings and fertilizer management on yield, nutrient content and uptake of rice (*Oryza Sataiva* L.). *The Bioscan*. **10(1):** 351-353.

Deqiu, Yang. Xinming, Hao. Jiandong, Li. Yang, Li. and Jingxia, Jia. 2010. Virtual design and experiments of four-row mounted potato planter-based on solidworks. *J. Agricultural Mechanization Research*. S223.93.

Dwivedi, Sanjay K. Meshram, M. R. Pal and Ashok, Kanwar, P. C. 2015. Effect of planting geometry and seedling density on growth and yield of scented rice under SRI based cultivation practices. *The Bioscan*. **10(1):** 455-458.

Hollewell, W. 1992. Drill performance assessments. *British Sugar Beet Rev*. **50(3):** 13-15.

Heege, H. J. 1993. Seeding methods performance for cereals, rape and beans. *Transactions of ASAE*. **36(3):** 653-661.

Jayan, P. R. and Kumar, V. J. F. 2004. Planter design in relation to the physical properties of seds. *J. Tropical Agriculture and Food Science* **42(1/2):** 69-71.

Kachman, S. D. and Smith, J. A. 1995. Alternative measures of accuracy in plants using single seed metering. *Transactions of ASAE*. **38(2):** 379-387.

Kamble, A. K., Rahate, R. H., Devagirikar, A. A., Diwane, L. P., Alurkar, H. P. 2003. Development evaluation of multipower operational cotton planter. *Bioved*. **14(1/2):** 29-32.

Kepner, R. A. Bainer, Roy and Barger, E. L. 1987. Principles of Farm Machinery.

Korayem, A. Y., Younis, S. M. and Hemada, A. M., 1986. Study of some factors affecting the accuracy of corn planters. Alexandria *J. Agricultural Research*. **32(2):** 27-46.

RNAM, Bangkok, Thailand. 1995. Agricultural machinery design and data handbook (Seeders and Planters).

Rui, Yuan. Xu, Ma. Cheng-lin, Ma. Wei, Wang. Xin, Qiao. Dan, Yang. 2006. Virtual manufacturing and motion simulation of precision planter unit. *J. Jilin University (Engineering and Technology Edition)*. **S223.2.**

Sahoo, P. K. and Shrivastava, A. P. 2000. Development of performance evaluation of okra planter. *J. Agricultural Engineering*. **37(4):** 15-25.

Santos, S. R., dos Neto, P. H. W., Fey, E. and Wobeto, C. 2003. Influence of soybean seed size in seeding processes. *Rev. Bras. Eng. Agric. Ambient.* **7 (1):** 177-181. (in Portuguese with English abstract).

Singh, R. C. Singh, G. and Saraswat, D. C. 2005. Optimization of design and opearational parameters of a pneumatic seed metering device for planting cottonseeds. *Biosystem Engineering.* **92(4):** 429-438.

Wu, Shihong. and Bao, Wenyu. 2015. Virtual prototype design of No-tillage planter based on solid-works. *Advance Material Research* **49(5):** 2769-2773.

Yadachi, Shiddanagouda. Mani, Indra. Karla, M. S. Kumar, Adarsh. and Sahoo, P. K. 2013. Development and evaluation of inclined plate metering mechanism for carrot seed. *J. Agricultural Engineering.* **50(2):** 10-16.

Yazgi, A. and Degirmencioglu, A. 2007. Optimization of the seed spacing uniformity performance of a vacuum-type precision seeder using response surface methodology. *Biosystem Engineering.* **97 (3):** 347-356.