UDK: 631.53.041

Originalni naučni rad
Original scientific paper

DEVELOPMENT AND EVALUATION OF METERING MECHANISM FOR MULTI-CROP PLANTER FOR HILLY REGIONS

Hijam Jiten Singh[*], Dipankar De, Pramod Kumar Sahoo

Indian Agricultural Research Institute, Division of Agricultural Engineering, New Delhi, India

Abstract: Inclined plate seed metering device was designed and evaluated in laboratory for singulation and uniform placement of maize and soybean seeds at three different cell shapes and sizes. The performance parameters like average spacing, multiple index, quality of feed index and precision were measured. Among the combinations of design variables, the seed metering plate with semi-circular cell shape having cell size 7 mm diameter was found to be the optimum for metering maize seed. Average spacing, quality of feed index, multiple index, miss index and precision were 17.48 cm, 79.33 %, 18.67 %, 2 % and 10.5 %, respectively. Likewise, the seed metering plate with semi- circular cell shape having cell size of 12 mm diameter was found to be optimum for metering soybean seed. Average spacing, quality of feed index, multiple index, miss index and precision were 9.65 cm, 77.33 %, 14.33 %, 8.34 % and 18.73 %, respectively. Therefore, considering all the performance parameters, inclined plate metering device with semi-circular shape of cell diameters 7 mm and 12 mm were selected for maize and soybean seeds, respectively.

Key words: Maize, soybean, NEH region, inclined plate metering device, performance indices, semi-circular cells

INTRODUCTION

The ultimate objective of planting using improved sowing equipment is to achieve precise seed distribution within the row for its proper growth. It is necessary for seeds to

---

[*] Corresponding author E-mail: hijam_jiten@yahoo.co.in

be placed at required distance apart within rows. Various seed drill and planters with different metering mechanisms have been developed, evaluated and reported by various researchers in literature, i.e. [3] [4] [5] [8] [11] [15] [16] [17]. In manual seeding with conventional practice, the higher and non-uniform plant population adversely affect grain yield of different crops [14]. The seed spacing majorly depends on the machine technical variables such as the type of seed pickup mechanism, machine operating speed, overall gear ratio between drive wheel and seed plate, and also on seed quality to some extent. Further, a number of others factors affect the spacing of plants. The device may pick and drop multiple seeds resulting in small spacing between seeds [13]. The proper design of a seed metering mechanism is essential for satisfactory performance of any seed planter. Besides, seed tube design and soil conditions along with other factors determine the final placement of seed. Although there are many planters having different seed metering mechanisms, the application of single seed metered plate mechanisms (inclined plate) has increased rapidly due to better seeding performance than that of other mechanical rotors.

Performance of single seed planter is related to the sowing uniformity of the distribution pattern along the length of the row. Under field conditions, direct measurement of seed placement is very difficult. Therefore, measurement of the spacing between plants after they emerge is an alternative. Much of the variability in spacing could be removed by evaluating planters under laboratory conditions. The assessment of plant spacing and seed rate as provided by the planters is also crucial in analyzing its performance. A variety of methods have been evolved to assess the performance of planter metering mechanism. Measuring the spacing between germinated plants after planting with machine is most common method. When examining the spacing between the plants once they emerge, considerable variability often exists in the plant-to-plant distance. The second most prevalently used method is the grease belt test rig under laboratory conditions, which is unaffected by crop and soil conditions. The main aim is to quantify the observed variability in a way that will allow one to make meaningful comparisons between single seed metering devices.

[12] designed and developed an inclined plate type metering unit having metering plates with cells of proper size and shape for maize seeds. The plates were made of cast aluminum 120 mm diameters. They had eight L-shaped cells at the periphery. The number of cells on the plate depended on the plant-to-plant spacing in a row and on the transmission ratio between the ground wheel and the metering plate. The seed plate was mounted at an angle of 60º with the horizontal so that the extra seed dragged along were dropped before reaching the seed outlet of the hopper. [10] developed a three-row bullock drawn multi-crop inclined plate planter at for sowing different type of crops. The plant population was found 10-12 plants per square meter.

[9] tested and compared the widely used measures; mean, standard deviation, quality of feed index, multiple index, miss index and precision. Those measures were based on the theoretical spacing (Xref), specified in ISO 7256-1 standard (1984) and gave a good indication of the spacing distribution. It was also concluded that the mean and standard deviation of seed spacing didn't offer an appropriate evaluation of planter performance on seed distribution. The final selection of metering device also depends on multiple index and miss index.

A large number of planter designs are available for plains areas, but very little information is available on planters with their suitable metering mechanisms which can be used for planting crops such as maize, soybean etc., in the hilly region particularly, NEH region which have different physical characteristics than those used for the plains. Physical and engineering properties of commonly available local varieties of maize and soybean have also not been studied earlier. Therefore, the objectives of study were to determine physical and engineering properties of seeds to develop and evaluate seed metering plate for maize and soybean crops, and recommend the optimum metering devices both for maize and soybean seeds from laboratory investigation.

MATERIAL AND METHODS

Metering System

Mechanical seed metering devices in planter usually have cells on a moving member to have positive seed metering. Commonly recommended metering systems on planters are horizontal plate, inclined plate, vertical rollers with cells, and cups over the periphery [2]. The seeds are handled gently by the inclined plate in comparison to other devices. The plates and outer cells are machined accurately to provide uniform cell size for precision planting of seeds. Since the risk of crushing unevenly sized seeds is greater, horizontal plate metering device is not considered. Laboratory experiment was thus conducted with inclined plate cell type metering mechanism having cells of different shapes and sizes for metering of maize and soybean seeds locally used in NEH region (Figs. 1-2). Details of the metering plates are shown in Fig. 3.
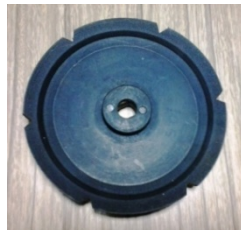
| a. Rectangular shape | b. L-shape | c. Semi-circular |

Figure 1. Metering plate with different cell shapes used for metering maize seed

| a. Rectangular shape | b. L-shape | c. Semi-circular |

Figure 2. Metering plate with different cell shapes for metering soybean seed

The types of maize (Murli Makai) and soybean (Raus 5) seeds used for the study are shown in Fig. 4. Tab. 1 showed that roundness and sphericity of both the types of seeds were close to one. The average angle of repose for the both the crops were 27º and 26º, respectively. The slope of the hopper walls, which was required to be more than the angle of repose of the seed, was selected as 30º considering standard deviation.
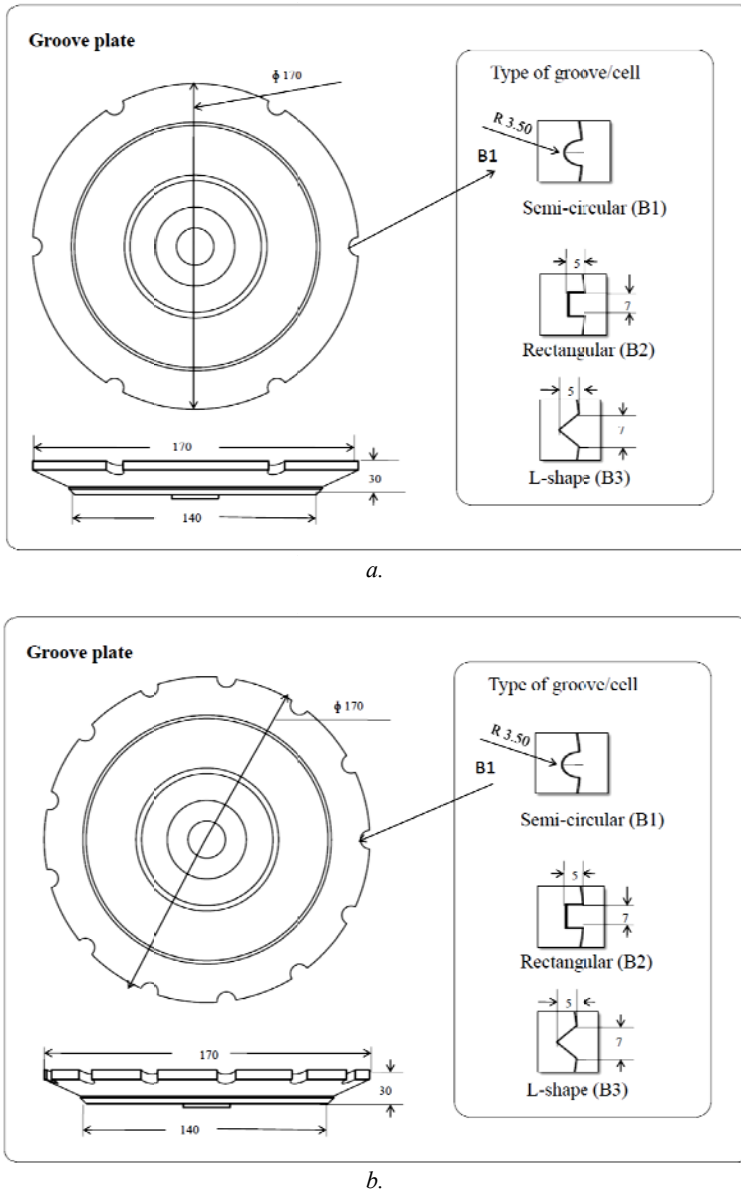

a.

b.

Figure 3. Details of metering plate used for: a. maize seed, b. soybean seed metering

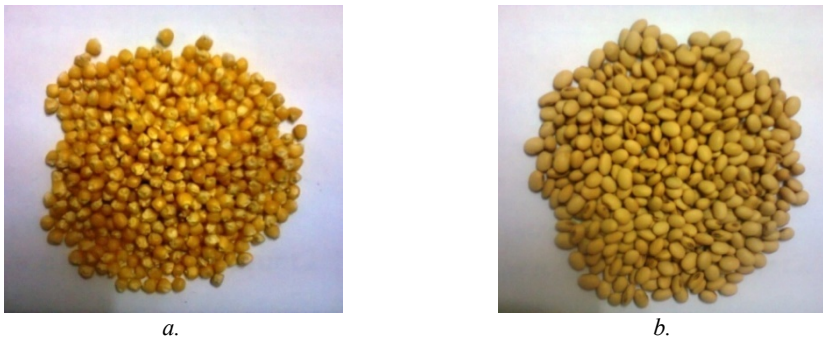*a.*   *b.*

Figure 4. Seeds used for the study: a. maize, b. soybean

*Table 1. Physical and engineering properties of maize and soybean seed
for design of metering mechanism*

Properties	Unit	Type of seed	
		Maize	Soybean
Length	[mm]	6.49±0.43	8.88±0.55
Breadth	[mm]	5.94±0.49	6.46±0.36
Thickness	[mm]	5.17±0.51	4.68±0.00
Sphericity	[-]	0.89±0.05	0.73±0.22
Roundness	[-]	0.86±0.07	0.66±0.02
Bulk density	[kg·m⁻³]	754.00±7.04	749.50±1.59
1000 seeds weight	[g]	137.80±1.83	177.55±3.04
Angle of repose	[°]	26.60±3.15	25.82±1.88

Source: [7]

Laboratory Test

    The performance of cells of different shapes was evaluated using a sticky belt test rig under laboratory condition by varying cell size of the metering device for both maize and soybean seeds (Tab. 2). The sticky belt mechanism consisted of 4 m long endless canvass belt mounted on two endless rollers spaced 100 cm apart along with a seed hopper and power transmission unit of belt pulley system with reduction gear and driving roller driven by a 4 kW motor. Observations were taken on the spacing between two adjacent seeds over the greased belt. Based upon the in-between spacing of 50 seeds, five measures of performance parameters viz. average spacing, multiple index, miss index, quality of feed index and precision were determined [9].

Table 2. Plan of experiments on metering device

Sl. No.	System variable	Levels of variable
1	Seed	Maize (S1), Soybean (S2)
2	Cell shape	Semi-circular (B1), Rectangular (B2), L-shape (B3)
3	Cell size	Maize: 7 mm (C1), 8 mm (C2), 9 mm (C3) Soybean: 10 mm (C4), 11 mm (C5), 12 mm (C6)

Table 3. Cell dimensions of seed metering plate

Cell dimension	Unit	Type of cell/groove					
		Maize seed			Soybean seed		
		Semi-circular	Rectangular	L-shape	Semi-circular	Rectangular	L-shape
Lenth	[mm]	-	7, 8, 9	7, 8, 9	-	10, 11, 12	10, 11, 12
Height	[mm]	-	5	5	-	5	5
Diameter	[mm]	7, 8, 9	-	-	10, 11, 12	-	-
Thickness	[mm]	5	5	5	5	5	5

Performance Parameters

Multiple index (*D*) is an indicator of more than one seed dropped within a desired spacing. It is the percentage of spacing that is less than or equal to half of the theoretical spacing:

$$D = \frac{n_1}{N} \tag{1}$$

Where:
n_1 [-] - number of spacings in the region ≤ 0.5 times of theoretical spacing,
N [-] - total number of observations.

Thus, it is an indication of more than one seed being dropped within a desired spacing.

Quality of feed index (*A*) is the percentage of spacings that are more than half, but not more than 1.5 times the theoretical spacing. It is the measure of how often the seed spacing's were close to the theoretical spacing. The quality of feed index is mathematically expressed as:

$$A = \frac{n_2}{N} \tag{2}$$

Where:
n_2 [-] - number of spacings between 0.5 and 1.5 times of the theoretical spacing.

Miss index (*M*) is an indicator of how often the seed skips the desired spacing. It is the percentage of spacing greater than 1.5 times the theoretical spacing.

$$M = \frac{n_3}{N} \tag{3}$$

Where:
n_3 [-] - number of spacing in the region ≥ 1.5 times the theoretical spacing.

Precision (*C*) is a measure of the variability in spacing after accounting for variability due to both multiples and skips. The precision is the coefficient of variation of the spacing that is classified as singles. Lower the value of coefficient of variation in singles better is the performance of metering mechanism It is mathematically expressed as:

$$C = \frac{S_2}{X_{ref}} \qquad (4)$$

Where:

S_2 [-]   - sample standard deviation of the n_2 observation,
X_{ref} [-]   - theoretical spacing.

Statistical Analysis. Using factorial RBD design the data analysis was done to see the effect of seed and machine parameters and their interactions. Then, the performance parameters were statistically analyzed using SAS software.

RESULTS AND DISCUSSION

Performance Indices of metering device for maize seeds

Average spacing was influenced by all combinations of design variables of the study at 5 % level of significance. Average seed spacings obtained with cell shape B1 and cell size C1, C2 and C3 were 17.48 cm, 16.28 cm, and 15.79 cm, respectively. For cell shape B2 and cell size C1, C2 and C3, average seed spacings were 15.57 cm, 14.72 cm and 14.46 cm, respectively. Similarly, average spacings with cell shape B3 and cell size C1, C2 and C3 were 37.31 cm, 32.20 cm and 21.43 cm, respectively. However, the performance was also influenced by other indicators as miss index, multiple index, and quality of feed index and precision of the metering device. Hence, only the average seed spacing could not draw any conclusion regarding selection of metering device.

Multiple index was influenced by cell shape and cell size of the metering device at 5 % level of significance. The cell shape of metering device influenced the multiple index the most, followed by cell size as indicated by the F-values, Tab. 4. Fig. 6 shows the performance indices of various combinations of design variables. It was found that multiple index was higher in case of semi-circular (B1) and rectangular (B2) shape cells of all sizes as compared to L-shape cells. The least multiple index was 5.67 % in case of seed metering plate with L-shape cells of size 8 mm (C2).

Miss index was influenced highly by all the design variables of study at 5 % level of significance. Cell shape influenced the most, followed by cell size as indicated by the F-values, Tab. 4. Fig. 6 indicates that seed metering by plate with L-shape cells resulted in more missing. The least miss index was 1.33 % for rectangular cell shape (B2) of cell size 9 mm (C3).

Quality of feed index (*QFI*) was highly influenced by cell shape, followed by cell size as indicated by F-values, Tab. 4. QFI decreased with increase in miss index, multiple index, or both (Fig. 6). QFI was highest for semi-circular shape seed metering plate and the maximum value was 79.33 % cell shape B1 of cell size C3.

Precision was most influenced by cell shape, followed by cell size at 5 % level of significance as indicated by F-values, Tab. 4. Fig. 7 shows that precision was lowest for semi-circular shape cells and the least value was 10.5 % for seed metering plate with cell size of 7 mm.

Table 4. F-values for performance parameters of maize seed metering mechanism

Source	F-value				
	Average spacing	Miss index	Multiple index	Quality of feed index	Precision
R	0.16	0.65	0.45	2.28	0.79
B	51.29*	554.36*	79.56*	123.74*	11.85*
C	7.15*	65.93*	20.77*	8.57*	0.85*
B*C	4.45*	42.20*	4.68*	13.86*	1.17*

* Significant at 5 % level of significance. R=Replication; B=Shape of cell; C=Size of cell

Table 5. F-values for performance parameters of soybean seeds metering mechanism

Source	F-value				
	Average spacing	Miss index	Multiple index	Quality of feed index	Precision
R	1.73	0.32	0.45	2.51	0.17
B	175.05*	361.72*	79.56*	253.04*	15.44*
C	94.94*	117.78*	20.77*	69.57*	4.75*
B*C	32.72*	31.99*	4.68*	45.27*	8.01*

* Significant at 5 % level of significance. R=Replication; B=Shape of cell; C=Size of cell

Selection of Metering Mechanism

Final metering system for maize seed was selected taking into account different performance parameters discussed above. Average seed spacing of maize was close to the theoretical seed spacing of 20 cm for NEH region for the plate with cell shape B1 and cell size C1 as compared to the remaining cell shapes and sizes. The highest quality of feed index observed was 79.33 % for semi-circular cell shape and cell size 7 mm diameter. The least value of precision was 10.50 % for cell shape B1 of size C1. It could thus be seen that semi-circular cell of 7 mm size gave highest precision. Hence, considering all the performance parameters among the combinations of design variables, inclined plate metering device with semi-circular cell shape having cell size of 7 mm and 5 mm deep was found optimum and was selected for metering maize seed.

Performance indices of metering device for soybean seeds

Average speed spacing was influenced by all combinations of design variables of the study at 5 % level of significance. Average seed spacings obtained with cell shape B1 and cell size C4, C5 and C6 were 41.20 cm, 19.44 cm and 9.65 cm, respectively. For cell shape B2 and cell size C4, C5 and C6, average seed spacings were 8.38 cm, 8.85 cm and 7.72 cm, respectively. Similarly, average spacings with cell shape B3 and cell size C4, C5 and C6 were 36.51 cm, 29.87 cm and 21.12 cm, respectively. As in case for maize seeds, cell shape and cell size highly influenced the performance parameters for soybean seeds as also average seed spacing, multiple index, miss index, quality of feed index and precision. Cell shape of metering plate influenced the average seed spacing the most, followed by cell size as indicated by F-values, Tab. 5. However, only the average seed spacing could not draw any conclusion regarding selection of metering device as the performance is influenced by other indicators discussed above.
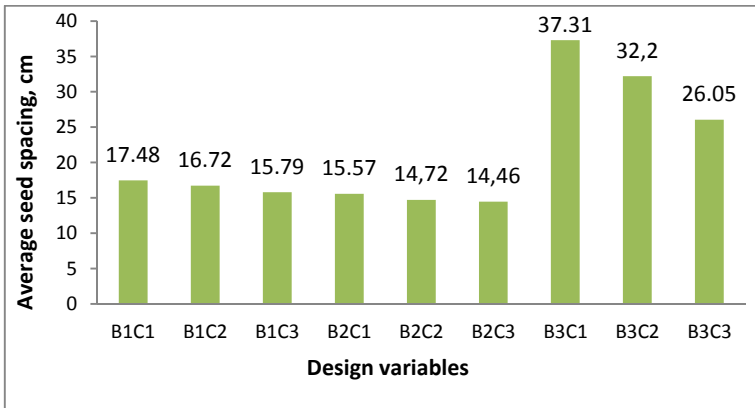
Figure 5. Average seed spacing of metering device with different cell types for maize seeds
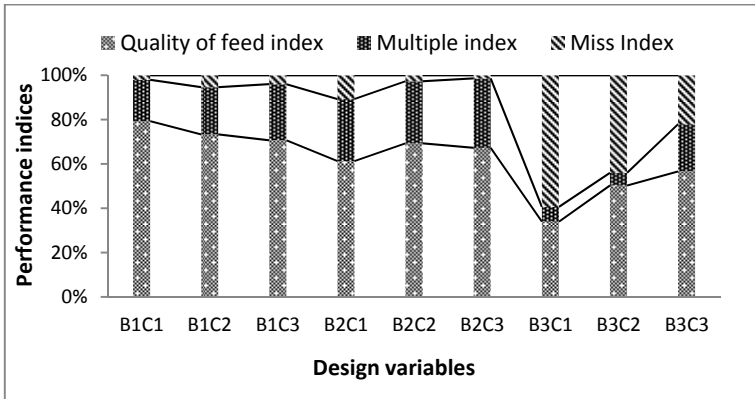

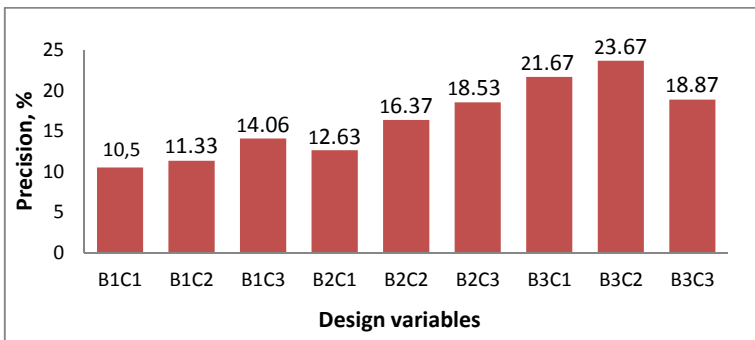*Figure 6. Performance of metering device for maize seeds*

Figure 7. Precision of metering device for combinations of design variables for maize seeds

Multiple index was influenced by cell shape and cell size of the metering device at 5 % level of significance. The cell shape of metering device influenced the multiple index the

most followed by cell size as indicated by the F-values, Tab. 5. Fig. 9 showed the performance indices of various combinations of design variables. For soybean seed, multiple index was irregular. There was no multiple for semi-circular cell of size 10 mm diameter (C4). The maximum multiple index was 28.67 % for rectangular cell shape and cell size C6.

Miss index was highly influenced by all the design variables of study at 5 % level of significance. Cell shape influenced the most, followed by cell size as indicated by the F-values, Tab. 5. Fig. 9 showed that seed metering by plates with semi-circular (except cell size C3) and L-shape cells resulted in more missing. The least miss index was 8.34 % for cell shape B1 of cell size 12 mm (C6).

Quality of feed index (*QFI*) was highly influenced by cell shape, followed by cell size as indicated by F-values, Tab. 5. QFI decreased with increase in miss index, multiple index or both (Fig. 9). Quality of feed index was highest for semi-circular cell shape with maximum value of 77.33 % for semi-circular cell shape (B1) and cell size 12 mm diameter (C6).

Precision was influenced by cell shape the most followed by cell shape at 5 % level of significance as indicated by F-values, Tab. 5. The least value of precision was 18.16 % for L-shape cell of size C5. It was also found that precision values for semi-circular shape cells were also close to the least value, Fig. 10.

Selection of Metering Mechanism

As in case of maize seed, final metering system for soybean was also selected taking into account different performance parameters discussed above. Average soybean seed spacing of 9.65 cm was close to the theoretical seed spacing of 10 cm for the plate with semi-circular cell shape (B1) and cell size of 12 mm diameter (C6).
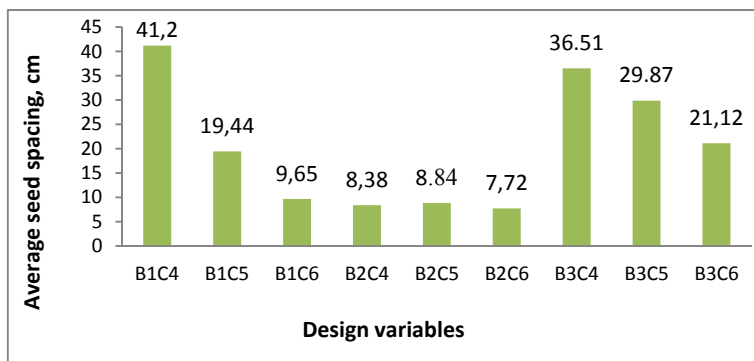

Figure 8. Average seed spacing of metering device with different cell types
for soybean seeds

The highest quality of feed index observed was 77.33 % for semi-circular cell shape (B1) and cell size of 12 mm (C6). The least miss index was 8.34 % for cell shape B1 of cell size C6. Hence, considering all the performance parameters, inclined plate metering device with semi-circular cell shape having cell size 12 mm and 5 mm deep was found optimum and was selected for metering soybean seed.
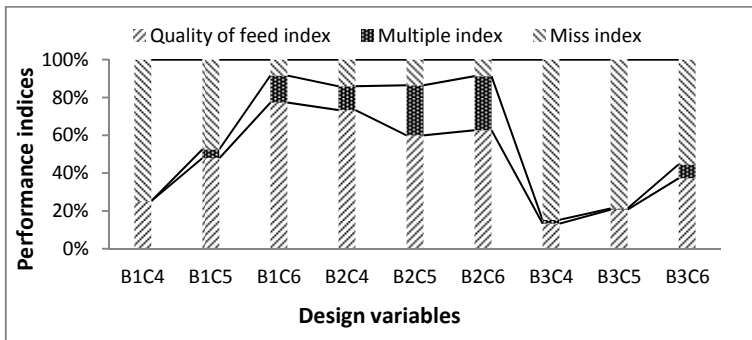
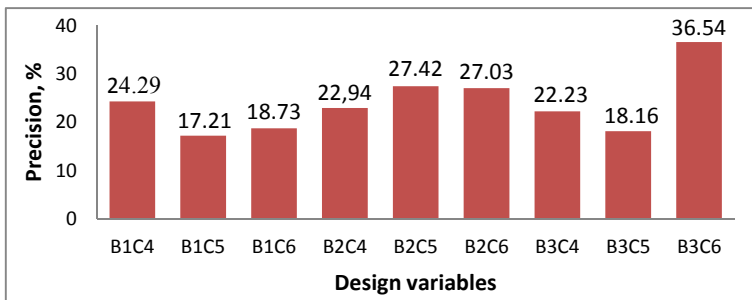*Figure 9. Performance of metering device for soybean seeds*

Figure 10. Precision of metering device for combinations of design variables for soybean

CONCLUSIONS

The average seed spacing, quality of feed index, multiple index and precision of the distribution of maize and soybean seeds along the length of the row were significantly influenced by cell shape, cell size and seed type. Inclined metering plate with semi-circular cell of 7 mm diameter and 5 mm deep gave average spacing, quality of feed index, multiple index, miss index and precision for this combinations were 17.48 cm, 79.33 %, 18.67 %, 2 % and 10.5 %, respectively for maize indicating best performance. For soybean seed, the seed metering plate with semi-circular cell shape having cell size of 12 mm and 5 mm deep was found to be optimum providing average spacing, quality of feed index, multiple index, miss index and precision for this were 9.65 cm, 77.33 %, 14.33 %, 8.34 % and 18.73 %, respectively.

REFERENCES

[1] Anon. 1984. *Sowing equipment-Test methods-Part I: Single seed drills* (Precision drills). ISO:7256/1, Geneva, Switzerland.

[2] Anon. 1991. *Agricultural Machinery Design and Data Handbook (Seeders and Planters)*. RNAM, Bangkok, Thailand.

[3]   Bakhtiari, M.R., Loghavi M. 2009. Development and evaluation of an innovative garlic clove precision planter. *J. Agric. Sci. Technol*., 11:125-136.

[4]   Celik, A., Ozturk, I., Way, T.R. 2007. Effects of various planters on emergence and seed distribution uniformity of sunflower. *Applied Engineering in Agriculture,* 23(1): 57-61.

[5]   Chetan, P.W., Kotwal, M.R. 2014. A review paper on various seed sowing metering devices. *IJPRET*, 2 (9): 429-435.

[6]   Ebrahim, A., Gudarz, A., Moez, J.M. 2009. Evaluation of various planters on seed rate, emergence, sowing depth and seed distribution uniformity of canola. *Journal of Agricultural Science,* 18(4):211-221.

[7]   Hijam, J.S. 2013. Development of multicrop planter for hill agriculture. Unpublished M.Tech. Thesis, Division of Agricultural Engineering, IARI, New Delhi, India, pp: 56-58.

[8]   Javad, T., Reza A., Ali, J. 2013. Design and evaluation of three metering devices for planting of sugarcane billets. *Journal of Agricultural Sciences,* 20:164-174.

[9]   Kachman, S.D., Smith, J.A. 1995. Alternative measures of accuracy in plant spacing for planters using single seed metering. *Trans. ASAE*, 38 (2): 379-387.

[10] Nirala, S.K. 2011. Performance evaluation of bullock drawn multi crop inclined plate planter. *Internat. J. Agric. Engg*., 4(2): 193-199.

[11] Pedro, H., Weirich, N., Altair, J., Rodrigo, T.N., José, D., Luiz, C.G. 2012. Comparison of metering mechanisms of corn seed. *Eng. Agríc., Jaboticabal,* 32(5):981-988.

[12] Pradhan, P.L., Mishra, J.N., Paul, J.C., Nanda, S.K. 2011. Development and evaluation of a power tiller operated planter for maize. *Agricultural Mechanization in Asia, Africa and Latin America*, 42(4): 67-71.

[13] Shiddanagouda, Y., Indra Mani, Kalra, M.S., Adarsh Kumar, Sahoo, P.K. 2013. Development and evaluation of inclined plate metering mechanism for carrot seed. *Journal of Agricultural Engineering,* 50 (2): 10-16.

[14] Singh, H., Kushwaha, H.L., Mishra. 2007. Development of seed drill for sowing on furrow slants to increase the productivity and sustainability of arid crops. *Biosystems Engineering*, 98: 176-184.

[15] Singh, S., Vatsa, D. K. 2007. Development and Evaluation of a light weight power tiller operated seed drill for hilly region. *Agricultural Mechanization in Asia, Africa and Latin America*, 38(2):45-47.

[16] Verma, A.K., Dewangan, M.L. 2007. Design, development and evaluation of seed cum fertilizer drill. *Agricultural Mechanization in Asia, Africa and Latin America*, 38(2):33-37.

[17] Vineet, K.S., Sharma D.N., Kumar, D. 2013. Development and evaluation of tractor drawn inclined cell plate type Bt cotton planter. *Internat. J. Agric. Engg.*, 6(2):329-334.

RAZVOJ I OCENA RADA MERNOG MEHANIZMA ZA ŠIROKOREDNU SEJALICU NA BRDSKIM TERENIMA

Hijam Jiten Singh, Dipankar De, Pramod Kumar Sahoo

Indijski poljoprivredni istraživački institut, Odeljenje za poljoprivrednu tehniku, Nju Delhi, Indija

Sažetak: Merni uređaj sa kosom pločom za merenje izbacivanja zrna konstruisan je i ispitivan u laboratoriji. Ispitivani su pojedinačno polaganje i ujednačenost polaganja semena kukuruza i soje sa tri različita oblika i veličine ćelija. Mereni su parametri kao što su: srednje rastojanje, index umnožavanja, indeks kvaliteta punjenja i preciznost.

Među kombinacijama promenljivih veličina u konstrukcijama, merna ploča sa polukružnim ćelijama i prečnikom ćelije od 7 mm bila je optimalna za merenje izbacivanja semena kukuruza. Srednje rastojanje, indeks kvaliteta punjenja, index umnožavanja, indeks greške i preciznost iznosili su 17.48 cm, 79.33 %, 18.67 %, 2 % i 10.5 %, redom. Merna ploča sa polukružnim ćelijama i prečnikom ćelije od 12 mm bila je optimalna za merenje izbacivanja semena soje. Srednje rastojanje, indeks kvaliteta punjenja, index umnožavanja, indeks greške i preciznost iznosili su 9.65 cm, 77.33 %, 14.33 %, 8.34 % i 18.73 %, redom. Imajući u vidu sve parametre, merni uređaji sa kosim pločama sa polukružnim ćelijama prečnika 7 mm i 12 mm bili su izabrani za setvu semena kukuruza i soje, redom.