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Development and Laboratory Evaluation of Picker Wheel type Metering Mechanism for Tuberose and Gladiolus Corms

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Manual planting of Tuberose bulbs and Gladiolus corms is very tedious and labour intensive operation demanding for development of a suitable metering mechanism for planting of both the crops. Considering the need, a picker wheel type metering mechanism was developed and evaluated for planting of both the crops in linear soil bin for three levels of nominal spacing (15, 20 and 25 cm) and four levels of forward speed (1.5, 2.0, 2.5 and 3.0 km/h). The experimental results indicated highest Quality of Feed Index (QFI) as 91.5 and 91.6% at forward speed of 1.5 km/h for Tuberose bulbs and Gladiolus corms respectively. The quality of feed index, coefficient of uniformity and CP3 values decreased whereas missing index and precision values increased with respect to increase in forward speed of the metering unit for all the three nominal spacings. Maximum visible damage was observed at higher levels of forward speeds for lower nominal spacings. The overall performance of the metering unit was found satisfactory for higher nominal spacings and at lower levels of forward speed.

Key words: Mechanization, Planter, Precision, Sowing, Spacings

Introduction

Government of India has identified floriculture as a sunrise industry and accorded it 100% export oriented status. Owing to steady increase in demand of flower, floriculture has become one of the important commercial trades in agriculture. Gladiolus (*Gladiolus dalenii*) and Tuberose (*Polianthes tuberosa L*.) are the two most important tropical ornamental bulbous flowering plants which are cultivated for their long lasting flower spikes. Tuberose is popularly known as Rajanigandha or Nishigandha. The total area under Tuberose cultivation in the country is about 16,190 ha. The production of loose and cut flowers is estimated to be 0.107 million MT and 8929 Million respectively. While total area under Gladiolus production is about 11,660 ha in the country with an estimated production of 1060 million cut flowers (Anonymous, 2017).[1] Generally, these two crops are planted at a recommended spacing of 30 × 25, 30 × 20 and 30 × 15 cm. Depending upon the geographical locations the seed rate may vary and requires about 1,33,334; 1,66,667 and 2,22,223 bulbs per hectare at mentioned spacing. Gladiolus can be grown in wide range of soils varying from light sandy to clay loam soils. It is propagated by its corms that are planted on ridge and furrow system with a distance of 30 cm between furrows and 15 to 25 cm between plants within the furrow at a depth of 7–10 cm. In general, the bulbs/corms of these flowering plants are planted manually requiring 220 man-h/ha. The planting operation is very tedious and time consuming.[2] Also due to non-availability of agricultural labourers, during the peak season, farmers face difficulty in timely planting of these two crops. Hence, mechanization of planting operation is need of the hour.

Numbers of researchers have developed precision planting mechanisms for small to medium sized grain seeds but very few have developed for planting of corms/bulbs. Four-row Gladiolus planter for planting of Gladiolus corms have been developed and evaluated at four levels of forward speeds of 1, 1.5, 2.0 and 2.5 km/h for 3 nominal spacing i.e. 15, 20 and 25 cm. The authors reported higher coefficient of uniformity and quality of feed index at lower forward speed for wider nominal spacing. Missing percentage was reported to increase with increase in forward speed of the planter.[3] Some other researcher designed and tested an air suction potato seed metering device. The optimized results indicated multiple index of 1.1%, miss index as 0.8% and quality of feed index as 98.9% for conventional tubers.[4] Tractor drawn 6-row

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automatic planter with cup-chain metering mechanism was developed for planting of Gladiolus corms. The result of field evaluation indicated quality feed index of 99% with no visible damage to the corms.[5] Similarly, optimized design of an electrical cup-chain potato metering device was developed. The authors reported that missing index increased with the increase in chain speed.[6] From the literature cited above, it has been observed that very limited research has been carried out on metering devices for planting of Tuberose bulbs and Gladiolus corms.

The conventional way of planting Tuberose bulbs or Gladiolus corms by the farmers is to mark line in the field, open a shallow furrow with the narrow blade spade, place the bulb/corm in the opened furrow lines and thereafter cover the bulbs with the soil. This method of planting is very tedious, time consuming operation and involves human drudgery. The literature cited reveals that only tractor drawn planter have been developed at G. B. Pant University of Agriculture (GBPUA&T), Pantnagar for planting of Gladiolus corms but no one else have developed planter for Tuberose bulbs till date. Hence, there is need to develop a precision metering mechanism which may be able to plant both the crops i.e. Tuberose bulbs and Gladiolus corms with little or no modification in its metering mechanism. In this endeavour, a suitable metering mechanism has been developed and the same has been evaluated in linear soil bin for planting of corms/Bulbs of both the crops.

Materials and Methods

The picker wheel type metering mechanism was designed, developed and fabricated in the workshop of department of Farm Machinery and Power Engineering, College of Technology, GBPUA & T for planting of both Tuberose bulbs as well as Gladiolus corms.

The picker wheel type metering mechanism consists of circular disc, finger, bulb/corm carrier, hopper, delivery pipe, shaft, and frame. Circular disc is made of mild steel having diameter of 600 mm and thickness of 4 mm (Fig. 1). On the periphery of this circular disc, fingers and bulb/corm carrier is placed with nut and bolts. It is mounted on the frame with the help of shaft and ball bearings. Finger consists of finger rod, finger rod holder, MS flat and torsional spring. It is made of mild steel with a total length of 160 mm and bent to 90° at 90 mm length and it is hold by finger rod holder (Fig. 1). Finger rod is held in tension with the aid of torsional spring mounted on the rod. Finger rod holder is mounted on the periphery of circular disc with nut and bolt. This holder is made of MS flat with dimensions as length, width and thickness of 100, 30 and 3 mm respectively. Flat is bent to U-shape at 30 mm either side, i.e. actual length of flat is 60 mm after making it into U-shape. Torsional springs are fixed in between U-shaped flat and another flat. The mild steel flat is welded to finger rod on one side having size of 65 mm length, 20 mm width and 4 mm thickness. Corm carrier was fabricated based on considering the engineering properties of Tuberose bulbs and Gladiolus corms (Table 1). It consists of bulbs carrying rods and base plate. The base plate is mounted on the periphery of circular disc with the help of nut and bolt. The size of the base plate is 110 mm long, 20 mm wide and 4 mm thick. On one side of the base plate, three bulb carrying rods of 4 mm diameter and 55 mm in length are welded at a spacing of 15 mm with each other. MS sheet hopper has been provided with a capacity of

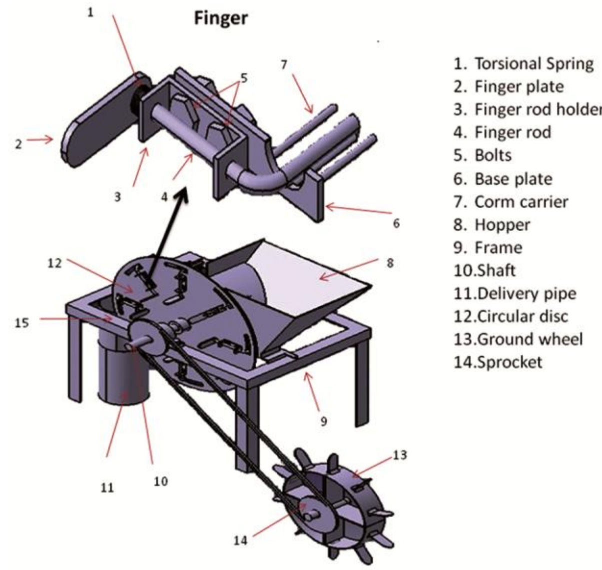

Fig. 1 — Schematic Diagram of picker wheel type metering mechanism

Table 1 — Physical properties considered for the development of metering mechanism

Sl. No.	Properties	Tuberose Values (SD)	Gladiolus Values (SD)
1	Major diameter	54.82 (3.77)	43.48 (3.74)
2	Intermediate diameter, mm	19.42 (2.44)	34.46 (2.90)
3	Minor diameter, mm	16.17 (2.71)	25.74 (2.96)
4	Geometric mean	29.6 (2.17)	33.91 (1.08)
5	Sphericity	0.435 (0.051)	0.77 (0.04)
4	Bulk density, g/cc	0.656 (0.023)	0.58 (0.05)
5	Angle of repose, Degree	37 (2.24)	32.00 (3.54)
6	Coefficient of friction (MS)	0.56 (0.013)	0.54 (0.018)

about 4 kg. The hopper was made trapezoidal in shape with two side walls having an inclination of 45° for easy flow of corms/bulbs towards the bottom (Fig. 1). Delivery pipe is made of Poly Vinyl Chloride (PVC) material having 76.2 mm diameter and was attached to the frame to deliver the bulbs/corms directly to the furrows. Diameter of the delivery pipe was selected in such a way so that the bulbs/corms have straight fall without striking the inner wall.[10] MS shaft of 25 mm diameter has been used to drive the circular disc. Frame of the metering mechanism has been made from MS angle iron of size 30 × 30 × 3 mm.

Working Principle of Metering Mechanism

Refer to the Fig.1 the circular disc gets drive from ground wheel (13) with a suitable chain and sprocket arrangement (14). The fingers were pressed against the circular disc (12) on one side, while the spring loaded rods with sleeves on the other side. As the circular disc rotate, the corm carrier (7) will get pass through the bars at the bottom of hopper (8) and Tuberose bulbs or Gladiolus corms will get into corm carrier. As soon as the corm carrier passes through hopper bottom suddenly the finger will get release from tension of torsional springs (1) and hold the corms by finger rod which will carry to other side of the disc where the corms will get released in to the furrow through delivery pipe (11) when the finger touches the cam (15) and the finger plate which is fixed with torsional spring will be under tension. Again the process repeats that the corm carrier passes through hopper bottom and picks the corms or bulbs and delivers it into the delivery pipe.

Performance Evaluation

The experiment was carried out in linear soil bin (Fig. 2) under controlled condition. The soil bin is made of RCC with length, width and height as 25 × 1.2 × 1 m. Brick posts of square cross section with sides as 0.228 m are provided on both the side walls over which two side rails are mounted along the length of soil bin. These side rails guide and facilitate the linear movement of a trolley fitted with metering unit. The trolley can be moved both forward and backward also its speed can be varied with the help of an electric motor (3 phase, 10 hp and 1440 rpm) fitted with the setup. The soil bin is filled with locally available silty-clay-loam soil up to a depth of 0.6 m for conducting the experiment. The developed picker wheel type metering mechanism was evaluated at four levels of forward speeds (1.5, 2.0, 2.5 and 3.0 km/h) and three levels of nominal spacings (15, 20 and 25 cm). Performance indices namely miss index, multiple index, quality of feed index, coefficient of uniformity, coefficient of precision (CP3 values), precision and the visible damage were considered for the experiment. Data was analyzed in 2 factorial design using Design Expert software.

Fig. 2 — Linear Soil bin

Multiple Index: It is the percentage of spacing that are less than or equal to half of the targeted spacing.

$$\text{Multiple Index} = \frac{n_1}{N}$$

where n_1 is number of spacings ≤ 0.5 times targeted spacing, N is the total number of observations recorded.

Miss Index: It is the percentage of spacing greater than 1.5 times the targeted spacing in cm.

Miss Index = n_2/N where n_1 is the number of spacings >1.5 times the targeted spacing

Quality of Feed Index: It is the percentage of spacing that are more than half but not more than 1.5 times the targeted spacing.

Quality of feed index = 100 – (Miss Index + Multiple Index)

Co-efficient of Uniformity: The average value of observed corm spacing was determined and the corresponding value of coefficient of uniformity was calculated using the following equation.

$$\text{Coefficient of uniformity } (C_u) = 1 - \left[\frac{\left| (X - \overline{X}) \right|}{N\overline{X}} \right] \times 100$$

C_u= Coefficient of uniformity, X = sum of absolute value, cm $\overline{X}$ = Nominal spacing, cm
N = number of observations

***Coefficient of Precision (CP3)*:** It is also known as 3 cm mode range and was determined for the better representation of performance of metering device to space seeds or plants near the targeted spacing than the combination of average spacings and standard deviation.[7]

Precision: Precision (C) is a measure of the variability in spacing after accounting for variability due to both multiples and missing index.

$$C = \frac{S_2}{X_{ref}}$$

where, S_2 = Sample standard deviation of the n3 observations i.e. spacing between 0.5 to 1.5 times the theoretical spacing, X_{ref} = Theoretical spacing.

Visible Damage: The percentage of visible damage caused by the metering unit was calculated by observing the physical visible damage of the corm after passing it through the metering device. The corms dropped in furrow was collected and observed for any physical visible damage and the data related to this were recorded. The percentage of corm damage was calculated using the following relationship.

$$\text{Visible damage \%} = \frac{\text{Number of damaged corms in 15 meter length in soil bin}}{\text{Total number of corms dropped in 15 meter length in soil bin}} \times 100$$

Results and Discussion

Mean Spacing

The actual bulb spacing was measured for all the forward speeds and nominal spacings. The result (Table 2) indicated that the observed spacing increased with increase in forward speed of the metering mechanism. However, it is quite closer to the required nominal spacing of the bulbs/corms. The highest deviation from the mean and coefficient of variation for Tuberose bulbs was observed as 5.54 cm and 23.10% respectively, whereas for Gladiolus corms, it was observed as 5.35 cm and 23.13% respectively. The data also indicated that the deviation of mean spacing increased with increase in forward speed of the metering unit. The reason could be vibration occurred in the fingers while picking up and releasing the bulbs/corms. Further, the coefficient of variation is also found increase with increase in forward speed of the metering unit. Similar results for tractor drawn 4-row gladiolus planter were reported while testing in field condition.[3]

Multiple Index

Multiples were occurred when more than one bulb or corm is delivered by metering device due to picking of smaller size of bulbs or corms as compared to finger size. This is because the bulbs/corms were not graded properly which is very essential to achieve uniform picking by fingers. The percentage of multiples of bulbs/corms for all the three nominal spacing and four forward speeds of operations were determined from 15 meter long test run in linear soil bin during the laboratory test and the results have been depicted in Fig. 3 for both Tuberose bulbs and Gladiolus corms. The figure witnessed that the multiple index declined with increase in forward speed of the metering unit for both Tuberose as well as Gladiolus corms. The reason may be that less time available to pick the bulbs/corms by fingers from the hopper of the metering unit and also may be due to the occurrence of more vibration at higher forward speed. Similar findings were reported in many other

Table 2 — Mean spacing of Tuberose bulbs and Gladiolus corms during evaluation

Nominal Spacing, cm	Forward speed, km/h	Tuberose				Gladiolus			
		Mean, cm	Ratio of mean/ nominal spacing	SD, cm	CV, %	Mean, cm	Ratio of mean/nominal spacing	SD, cm	CV, %
15	1.50	15.12	1.00	1.83	11.32	15.59	1.03	2.64	16.56
	2.00	15.24	1.01	2.27	14.51	16.58	1.10	2.72	16.39
	2.50	16.17	1.07	2.43	15.92	18.50	1.23	3.65	19.74
	3.00	17.64	1.17	2.96	16.78	18.86	1.25	3.70	19.60
20	1.50	22.00	1.10	4.33	19.68	20.07	1.00	4.64	23.13
	2.00	22.80	1.14	4.94	21.66	20.69	1.03	4.06	19.63
	2.50	23.57	1.17	5.21	22.10	23.90	1.19	3.71	15.54
	3.00	23.98	1.19	5.54	23.10	21.79	1.08	3.61	16.58
25	1.50	22.45	0.89	2.81	12.51	24.82	0.99	5.35	21.58
	2.00	23.41	0.93	4.20	17.95	22.33	0.89	4.26	19.08
	2.50	24.54	0.98	4.31	17.56	27.00	1.08	2.96	10.95
	3.00	23.46	0.93	4.83	20.61	28.05	1.12	4.46	15.90

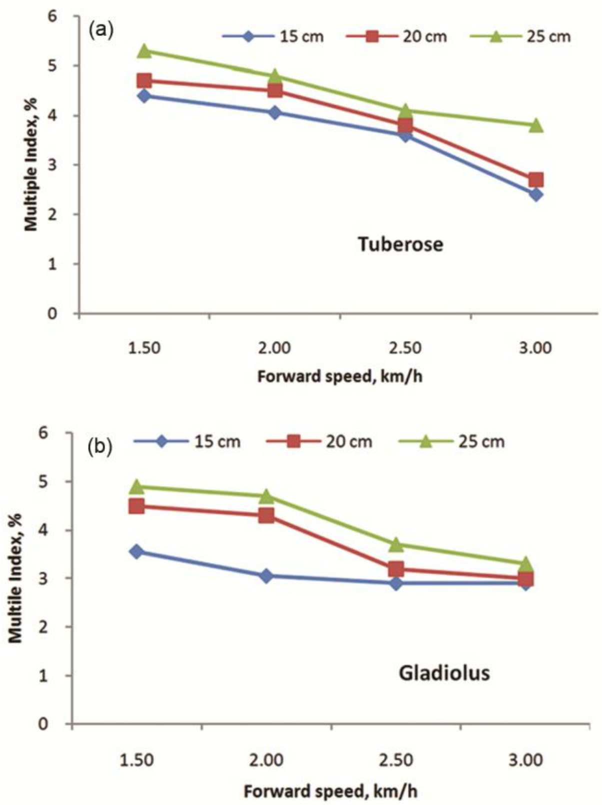

Fig. 3 — Effect of forward speed on multiple index for different nominal spacing

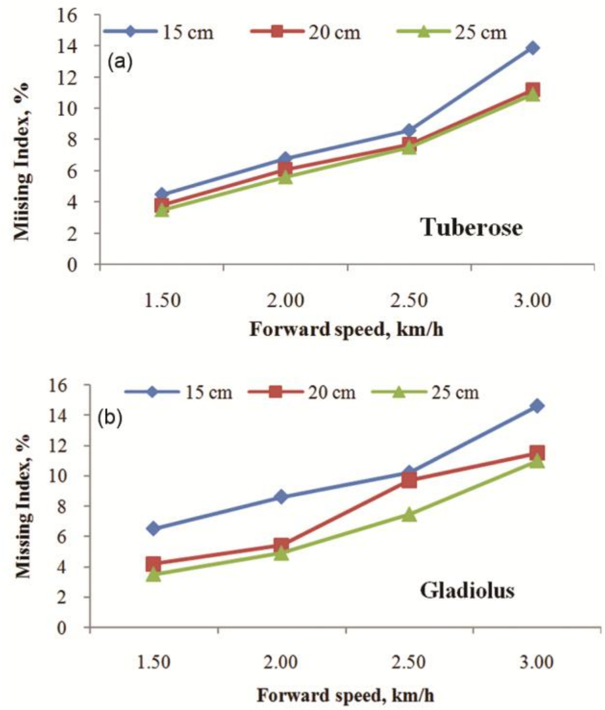

Fig. 4 — Effect of forward speed on missing index for different nominal spacing

studies.[8–10] Also it was observed that the minimum values of multiple index were found for lower nominal spacing (15 cm) as compared to higher nominal spacing (25 cm). Further the forward speed and nominal spacing significantly affects the multiple index at 1% level of significance for both Tuberose bulbs as well as Gladiolus corms whereas its interaction effect does not affect significantly (Table 2). Overall mean values of multiple index and coefficient of variation were observed as 4.01 and 14.91% respectively, which is not within acceptable limits. This indicates that the metering unit needs further design modifications to reach standardized acceptable limits.

Miss Index

Skips or misses occurred when finger fail to pick up the bulbs and deliver into the furrow through delivery pipe. In present study lower values of miss index indicates better performance of the metering mechanism. As it can be seen from the Fig. 4, the average values of missing index increased with increase in forward speed of the metering unit in the linear soil bin for both Tuberose bulbs as well as Gladiolus corms. Missing index were also observed higher for lower values of nominal spacing and vice versa. These missings may be due to jerk or vibrations produced in fingers during operation of metering mechanism. It may also be due to the stucking of tuberose bulbs in between finger bars while picking up from hopper. The reason for increased values could be less available time to pick up the bulbs/corms from the hopper resulting in higher values of missing index at higher levels of forward speeds for lower nominal spacings. These results are in accordance with the findings of other researchers.[2,11] Also it is observed from Table 3 that the forward speed and nominal spacing affects missing index significantly at 1% level of significance whereas its combined effect doesn’t show any significant effect on the same for tuberose bulbs. Interaction effect of forward speed and nominal spacing show significant effect on missing index for gladiolus corms at 1% level of significance. Overall mean value of missing index for tuberose bulbs is less than that of gladiolus corms whereas the coefficient of missing is more for tuberose bulbs as compared to gladiolus corms. This indicates that more variation occurred for tuberose bulbs as the bulb size is not uniform and there may be disturbance in picking up

Table 3 — Statistical Analysis of various parameters (p-values)

	Tuberose					Gladiolus				
	Miss	Multi	QFI	CoU	CP3	Miss	Multiple	QFI	CoU	CP3
Speed (S)	0.0001**	0.0001**	0.0001**	0.0001**	0.0001**	0.0001**	0.0001**	0.0001**	0.003**	0.000**
Spacing (W)	0.0001**	0.0047**	0.075^{NS}	0.0306*	0.0001**	0.0001**	0.0001**	0.0001**	0.3615^{NS}	0.0001**
Interaction (S×W)	0.2242^{NS}	0.862^{NS}	0.5811^{NS}	0.7813^{NS}	0.8966^{NS}	0.0015**	0.0001**	0.001**	0.5979^{NS}	0.9737^{NS}
Std. Dev.	0.79	0.60	0.99	1.96	1.86	0.37	0.18	0.42	2.48	2.71
Mean	7.51	4.01	88.48	86.95	38.86	8.21	3.67	88.12	86.25	36.26
CV%	10.55	14.91	1.12	2.26	4.78	4.56	5.02	0.47	2.88	7.46

**Highly Significant at p≤ 0.01, *Significant at p≤0.05 & NS Not Significant

and dropping of tuberose bulbs as compared to gladiolus corms.

Quality Feed Index

Higher values of quality feed index indicates better performance of metering mechanism than its lower values. In other words, the quality of feed index is a measure of how often the spacings are closer to theoretical spacings. Results revealed that the mean value of quality of feed index is significantly affected by forward speed of the metering mechanism for both bulbs as well as corms (Table 2). Further, highest quality of feed index values were obtained at the forward speed of 1.5 km/h for higher nominal spacing of 25 cm (Fig. 5). These results are in close agreement with the findings of other researchers.[6] The nominal spacing doesn't show any effect on quality of feed index for tuberose bulbs whereas the same varies significantly at 1% level of significance for gladiolus corms. The interaction effect of forward speed and nominal spacing affects quality of feed index at 1% level of significance for Gladiolus corms whereas there is no significant interaction effect for tuberose bulbs.

Precision

Precision is a measure of the variability in spacings between bulbs/corms after accounting for variability due to both multiples and missings. A practical upper limit of precision is 10% for laboratory condition. Smaller values of precision indicate better performance than larger values.[6,12] However, the percent of precision was found greater than the desired values for both Tuberose bulbs and Gladiolus corms. Comparison of data on overall precision as affected by forward speeds and nominal spacing showed significantly higher values for the forward speed of 3.0 km/h as compared to the forward speeds of 1.5, 2.0 and 2.5 km/h (Fig. 6).

Coefficient of Uniformity

The coefficient of uniformity indicates the evenness of bulbs or corms falling in the furrow. The relationship between forward speed and coefficient of uniformity is illustrated in Fig. 7, which indicates higher coefficient of uniformity for higher nominal spacing at lower speed of operation. This may be due to the fact that the fingers of metering unit get sufficient time for picking up bulbs/corms and vice versa. It is also evident from the Fig. 7 that the lower values for both Tuberose and Gladiolus corms were obtained for lower nominal spacing (15 cm) and higher forward speed (3 km/h). This may be due to the fact that more vibration may occur at higher level of forward speed as compared lower forward speeds. The statistical analysis (Table 3) shows significant effect of forward speeds and nominal spacings on coefficient of uniformity for Tuberose bulbs at 1%

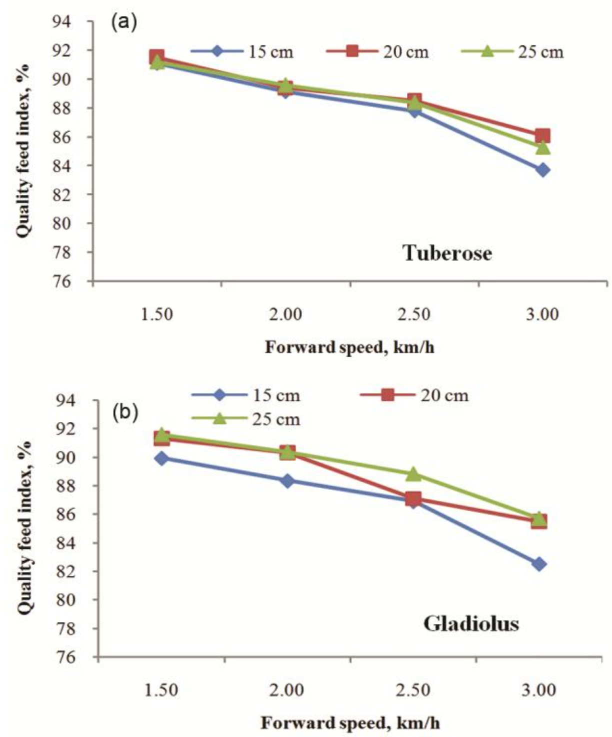

Fig. 5 — Effect of forward speed on quality of feed index for different nominal spacing

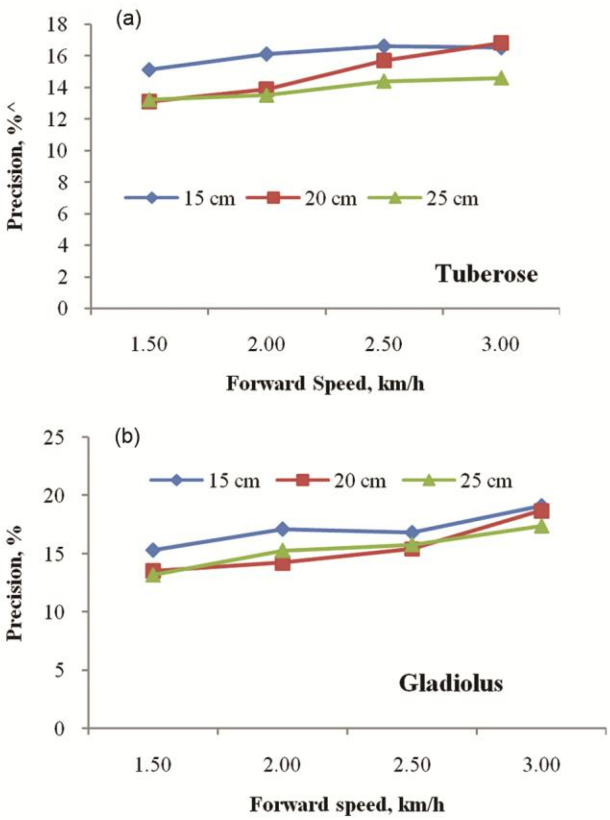

Fig. 6 — Effect of forward speed on precision values for different nominal spacing

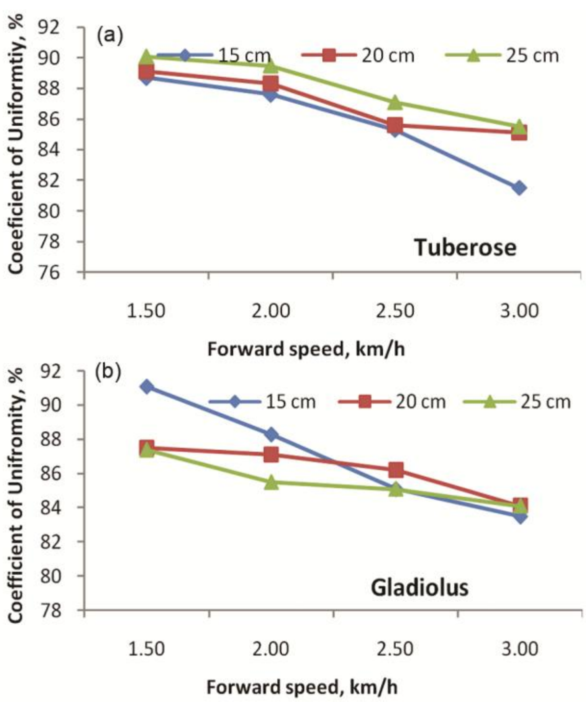

Fig. 7 — Effect of Forward speed on coefficient of uniformity for different nominal spacing

level of significance whereas for Gladiolus corms only forward speed shows the significant effect on coefficient of uniformity.

Coefficient of Precision (CP3)

Higher CP3 values are desirablefor better performance of metering device.[8] The mean values of CP3 decreased with increase in forward speed of metering unit as well as nominal spacing for both Tuberose bulbs and Gladiolus corms (Fig. 8). However, the mean CP3 values do not reach more than 45% for both Tuberose bulbs as well as Gladiolus corms. As seen from the Table 2 that the forward speed and nominal spacing significantly affect the values of coefficient of precision at 1% level of significance and their interaction effect does not show any significant variation of values of coefficient of precision. Similar results have been reported by other researchers too.[8]

Visible Damage

The visible damage of bulbs or corms is commonly occurred during planting with the help of mechanical device. Visible damage of bulbs or corms may occur due to the reason that the bulbs may get stuck in between relative moving objects present in the metering unit. However, the damage of bulbs should

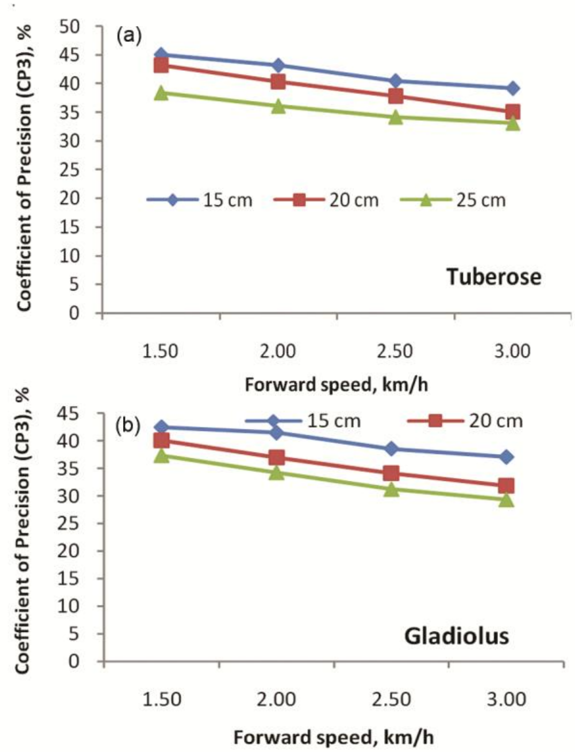

Fig. 8 — Effect of forward speed on Coefficient of precision for different nominal spacings

Table 4 — Visible damage of Tuberose bulbs and Gladiolus corms (%)

Forward speed km/h	Tuberose bulbs			Gladiolus corms		
	Nominal spacing, cm					
	15	20	25	15	20	25
1.50	10.5	8.8	7.6	8.3	7.5	5.1
2.00	11.1	9.4	8.4	8.5	8.12	6.47
2.50	14.1	10.8	9.2	11.1	9.54	8.05
3.00	15.3	11.4	10.3	13.3	10.4	9.12

be within the acceptable limits. It is evident from Table 4 that the visible damage has increasing trend with increase in forward speed whereas decreasing trend with increase in nominal spacing. This is due to the fact that at higher level of forward speed and for lower level of nominal spacing the peripheral speed of metering unit is higher than that of peripheral speed at lower level of nominal spacing and higher forward speed. The percent of visible damage is quite high for Tuberose bulbs as compared to Gladiolus corms. The reason could be due to irregular shape of Tuberose bulbs leading to higher mechanical injury while passing through the metering mechanism as compared to regular shape of Gladiolus corms.

Conclusions

On the basis of experimental results, it can be concluded that the multiple index, quality of feed index, coefficient of uniformity and coefficient of precision (CP3 values) decreased and miss index increased with increase in forward speed. The operating parameter i.e. forward speed was found to have significant effect on miss index, multiple index, quality of feed index, coefficient of uniformity and coefficient of Precision (CP3) values at 1% level of significance. The developed metering mechanism performed better at lower forward speeds of 1.5 and 2 km/h for all the nominal spacings. The overall performance of metering mechanism was found better for Tuberose bulbs as compared to Gladiolus corms.

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