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Development and Performance Evaluation of a Gladiolus Planter in Field for Planting Corms

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Abstract**—**Gladiolus is an important cash crop and is grown mainly for its elegant spikes. Traditionally the gladiolus corms are planted manually which is very tedious, time consuming and labor intensive operation. So far, there is no planter available for planting of gladiolus corms. With a view to mechanize the planting operation of this horticultural crop, a prototype of 4-row gladiolus planter was developed and its performance was evaluated in-situ condition. Cup-chain type metering device was used to place each single gladiolus corm in furrow at required spacing while planting. Three levels of corm spacing viz 15, 20 and 25 cm and four levels of forward speed viz 1.0, 1.5, 2.0 and 2.5 km/h was taken as evaluation parameter for the planter. The performance indicators namely corm spacing in each row, coefficient of uniformity, missing index, multiple index, quality of feed index, number of corms per meter length, mechanical damage to the corms etc. were determined during the field test. The data was statistically analyzed using Completely Randomized Design (CRD) for testing the significance of the parameters. The result indicated that planter was able to drop the corms at required nominal spacing with minor variations. The highest deviation from the mean corm spacing was observed as 3.53 cm with maximum coefficient of variation as 13.88%. The highest missing and quality of feed indexes were observed as 6.33% and 97.45% respectively with no multiples. The performance of the planter was observed better at lower forward speed and wider corm spacing. The field capacity of the planter was found as 0.103 ha/h with an observed field efficiency of 76.57%.

Keywords**—**Coefficient of uniformity, corm spacing, gladiolus planter, mechanization.

I. INTRODUCTION

FLORICULTURE in India has a long tradition and has served the purpose of meeting out the socio-culture requirements since time immemorial. India is the second largest country in the world next to China in terms of area under flower crops. The total area under flower crops during 2013-14 was estimated around 2.55 m-ha (NHB). Gladiolus is a high value flower crop grown mainly for its elegant cut spikes to fulfill the requirement of its domestic as well as international market. These flowers are in great demand especially for decoration during wedding ceremonies and exhibitions. It is the second most popular commercial cut flower next to rose but ranks first, both in area and production as well as returns per unit area, among the bulbous crop grown in the country. In the state of Uttarakhand, gladiolus rank first, among the cultivated flowers, with an area of about 1.35 thousand ha having a production of 2.02 thousand MT loose and 8.45 thousand MT of cut flower during the year 2013-14 [1]. Because of high return per unit area and government policy to boost horticulture in the state, the area under horticultural crops is expected to increase in future.

Traditionally, the method of planting gladiolus, as adopted by farmers, is to make shallow furrow with spade and putting the gladiolus corms manually in it at required spacing and thereafter covering the same with soil. This operation is very tedious, time consuming and results in low work rate. Also due to non-availability of agricultural laborers, during the peak season, the planting operation is jeopardized and therefore, mechanizing this operation is of utmost importance. A two-row saffron corm planter was developed [2] that was able to plant the corms at a row spacing of 22 cm with planting depth of 15 cm without damaging the corms. Cup shape type metering device (cups fitted on conveyor belt) was used to meter the corms. Review of literature indicates that a number of planters for various types of crops are commercially available in the country, but still no suitable planter is available for planting of gladiolus corms.

Considering the high labor requirement in its planting operation and also the importance of timely sown crops, the work on development of a gladiolus planter was undertaken.

II. MATERIALS AND METHOD

A 4-row gladiolus planter was developed for planting of gladiolus corms. It consisted of a frame, hopper, ridger tines, metering unit, depth control wheel, drive wheel, and hitch system. Fig. 1 shows the details of the developed gladiolus planter with their components' description in Table I.

A. Hitch System

The hitch system of the gladiolus planter was fabricated using mild steel flat section of 50x16 mm size. The mast height of the hitch system was kept 610 mm and the lower hitch point span was kept as 685 mm. The dimensions of the hitch system were kept in accordance with the Indian Standards (IS: 4468 (Part-I)-1997) for category-II hitches suitable for tractors in the power range of 40-100 hp.

B. Frame

The frame of the planter was rectangular in shape having overall length and width of 1800 and 600 mm respectively. The frame was made of mild steel pipe of hollow square x-section having 50 mm width and 5 mm thickness.

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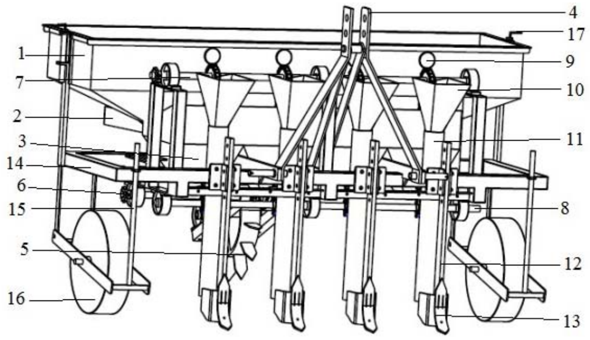

Fig. 1 Schematics of gladiolus planter

TABLE I
COMPONENTS OF PROTOTYPE

1	Main hopper	10	Delivery unit
2	Seed dropping tray	11	PVC pipe
3	Collecting hopper	12	Tine
4	Top link	13	Ridger
5	Ground wheel assembly	14	Frame
6	Driving shaft	15	Depth control bolt
7	Driven shaft	16	Gauge wheel
8	Metering	17	Box height adjustment bolt
9	Mild steel cup		

C. Main Hopper

The planter was provided with a common main hopper and individual collecting hoppers for each metering unit. The main hopper was designed for a capacity of 150 kg of gladiolus corms to minimize the number of fills during field operation. The upper portion of the main hopper was of rectangular shape with overall length and width of 1790 mm and 450 mm respectively. The lower portion of the hopper is in trapezoidal shape with wall inclination of 450 from the vertical. The wall inclination was kept higher than the angle of repose of the corms. An outlet of size 1190 x 170 mm has been provided in the bottom of the hopper for discharge of the corms from main hopper to collecting hopper. A floating mild steel pan has been fitted just under the opening of main hopper to control the flow of the corms from main hopper to collecting hopper. Provision has been made to adjust the height of the hopper to vary the flow rate of the corms.

D. Feeding Hopper

Further, a feeding-hopper separately for each metering unit has been provided with a capacity of 5 kg. It was made by using 2.5 mm thick mild steel sheet. The shape of the hopper is kept trapezoidal with top and bottom widths as 300 x 90 mm respectively. The depth the hopper is kept 200 mm with wall inclination of 450 for easy flow of the gladiolus corm without bridging. The gladiolus corms are scooped from this hopper by the cups provided with the metering unit.

E. Metering Unit

Cup-chain type metering unit has been used to place the gladiolus corms individually in furrows at desired spacing. Mild steel cups of size 60 x 25 mm have been fitted on a 130 cm long roller chain. Each roller chain has 13 numbers of such cups fitted at a spacing of 100 mm. The chain runs over two sprockets i.e. upper sprocket with 18 numbers of teeth and lower sprocket with 11 numbers of teeth. Both the sprockets are fitted on two mild steel shafts of 25 mm diameter. Similar units have been provided for all the four rows.

F. Discharge Funnel with Delivery Pipe

The metering unit collects the gladiolus corm individually into the cups and delivers the same into a 240 mm square funnel having a depth of 150 mm. A circular PVC pipe of 76.2 mm diameter was attached to the bottom end of the funnel to conduct the corms to the furrows. The size of the pipe was selected in such a way so that corms have straight fall without striking with the inner wall. Similar type of arrangement has been made for all the four rows.

G. Tines with Ridger

The gladiolus planter was developed to plant the gladiolus corms simultaneously in 4 rows at a row spacing of 300 mm. Accordingly four numbers of tines with ridger were fabricated using 730 mm long mild steel flat of size 50x16 mm for opening furrows. The upper ends of the tines were clamped with U-clamps on the front toolbar of the frame. Provision was made to adjust the length of tines for varying the depth of planting. At the lower end of each tine, 170 mm long and 45 mm wide ridger was fitted to obtain the furrows of required width. The mould board of the ridger was made from 5 mm thick heat treated mild steel sheet. Reversible shovels of 20 cm length were fitted in front of each ridger to opens the furrows of required depth. The rake angle of the shovel was kept 220 to minimize the draft requirement.

H. Depth Control Wheel

Two number of depth control wheels, each with 400 mm diameter and 100 mm face width, were provided, one at each side of the planter to maintain uniform depth of planting as well as to support the weight of the machine along with the corms in hopper. Provision was made to adjust the height of wheels in order to vary the depth of planting.

I. Drive Wheel

A floating type lug wheel with diameter 320 mm was provided to transmit the traction power of wheel to the metering unit through chain-sprocket drive. The wheel was located in the centre at the rear of the planter. A tension type helical spring of length 305 mm was provided that keeps the drive wheel always in contact with the ground surface to minimize wheel slippage.

J. Power Transmission

Provision has been made to transmit the power of the drive wheel to individual metering unit through chain-sprocket arrangement. The drive wheel is fitted with a sprocket having 30 numbers of teeth. It drives a primary shaft having three numbers of sprockets each with 30, 18 and 11 numbers of teeth. These sprockets have been provided to vary the speed ratio to obtain the nominal spacing of 15, 20 and 25 cm of the corms in furrows.

K. Performance Evaluation

The developed planter was evaluated in silty-clay-loam (sand: silt: clay as 36.2:47.6:16.2%) after preparing the seedbed nicely to assess its performance. The size of the test field for each experiment was taken as 20 meter long and 2.5 meter wide. The following independent parameters were considered during the testing.

- Speed of operation : 4 levels (1, 1.5, 2 and 2.5 km/h)
- Nominal corm spacing : 3 levels (15, 20 and 25 cm)

Each experiment was replicated five times to minimize the experimental error. The data regarding corm spacing in each row was measured and analyzed using methods namely missing index (MISS), multiples index (MULTI) and quality of feed index (QFI) as suggested by previous investigators [3]-[8]. Number of corms dropped per meter length in a row was also determined. Statistical parameter namely standard deviation (SD), coefficient of variation (CV) and coefficient of uniformity (CU) was also determined to predict the variations in corm spacing. The precision index (PREC) was also determined which is the coefficient of variation of the spacing after omitting the missed and multiple seed drop [4]-[7]. The parameters like visible mechanical damage, field capacity and field efficiency of the planter was also determined. The significance of the data was analyzed by using 2-way Completely Randomized Design (CRD). The following equations were used to determine the performance parameters.

$$CU = 1 - \left[\frac{\sum\left|X - \overline{X}\right|}{N\overline{X}}\right] x100 \quad (1)$$

where, CU=Coefficient of uniformity, X = sum of absolute value, cm, $\overline{X}$ = average of all observations, cm, N = number of observation

$$\text{Missing index (MISS), \%} = \frac{n1}{N} \times 100 \quad (2)$$

where, n_1= Number of spacing ≥ 1.5 times theoretical spacing, N= Total number of measured spacing

$$\text{Multiple index (MULT), \%} = \frac{n_2}{N} \times 100 \quad (3)$$

where, n_2 = number of spacing ≤ 0.5 times theoretical spacing, N = total number of measured spacing.

$$\text{Quality of feed index (QFI),\%} = 100 - (\text{MISS} + \text{MULTI}) \quad (4)$$

$$\text{Mechanical damage,\%} = \frac{\text{Damagedcormsin 5 meterdistance}}{\text{Totalnumberofcorms dropped in 5 meterdistance}} \times 100 \quad (5)$$

III. Results and Discussion

The gladiolus planter was evaluated in the field and the results have been discussed in this section.

TABLE II
Observed Mean Spacing of Corms During Field Test

Forward speed, km/h	rows	Nominal spacing 15 cm			Nominal spacing 20 cm			Nominal spacing 25 cm		
		Mean spacing	SD	CV	Mean spacing	SD	CV	Mean spacing	SD	CV
1 km/h (0.28 m/s)	1	15.15	1.59	10.51	20.79	2.02	9.71	25.81	1.96	7.61
	2	15.03	1.42	9.47	20.68	2.01	9.74	26.09	1.64	6.29
	3	15.01	1.69	11.27	20.72	2.10	10.14	26.34	1.94	7.38
	4	15.03	1.53	10.18	20.70	2.03	9.84	26.28	2.48	9.42
Overall mean		15.06	1.56	10.36	20.72	2.04	9.86	26.13	2.01	7.68
1.5 km/h (0.42 m/s)	1	15.04	1.75	11.63	20.30	2.13	10.46	26.36	2.06	7.81
	2	15.11	1.56	10.34	20.57	2.12	10.32	25.88	2.54	9.80
	3	15.08	1.64	10.87	20.24	2.39	11.82	26.74	2.35	8.80
	4	15.16	1.75	11.58	20.48	2.15	10.50	26.49	2.40	9.05
Overall mean		15.10	1.68	11.11	20.40	2.20	10.78	26.37	2.34	8.87
2 km/h (0.56 m/s)	1	15.07	1.52	10.11	20.50	2.23	10.87	25.93	2.38	9.16
	2	15.17	1.73	11.43	20.31	2.24	10.21	25.62	2.97	11.59
	3	15.01	1.66	11.05	20.03	2.31	10.89	25.89	2.03	7.83
	4	15.00	1.91	12.71	20.25	2.07	10.19	25.99	2.02	7.78
Overall mean		15.06	1.71	11.33	20.27	2.21	10.54	25.86	2.35	9.09
2.5 km/h (0.69 m/s)	1	15.13	2.05	13.55	20.34	2.86	14.10	25.84	2.85	11.01
	2	15.03	2.03	13.54	20.10	2.12	10.59	25.05	3.51	14.03
	3	14.66	1.94	13.26	20.10	2.39	11.89	25.88	3.93	15.19
	4	14.78	2.24	15.16	20.35	2.22	10.94	25.53	3.81	14.92
Overall mean		14.90	2.07	13.88	20.22	2.40	11.88	25.58	3.53	13.79

TABLE III
UNIFORMITY IN PLANTING OF GLADIOLUS PLANTER

Forward Speed, km/h	Nominal spacing, cm	Measures					
		Mean spacing, cm	MISS, %	MULT, %	QFI, %	PREC, %	Ratio of Mean/ Nominal spacing
	15	15.06	2.0	0	98.0	8.36	1.004
1.0	20	20.72	1.8	0	98.2	8.06	1.036
	25	26.13	0.8	0	99.2	6.88	1.045
	15	15.10	2.8	0	97.2	8.31	1.007
1.5	20	20.40	2.4	0	97.6	8.38	1.020
	25	26.37	1.4	0	98.6	7.47	1.055
	15	15.06	5.4	0	94.6	5.93	1.004
2.0	20	20.27	3.6	0	96.4	6.94	1.014
	25	25.86	2.6	0	97.4	6.49	1.034
	15	14.90	7.6	0	92.4	6.28	0.993
2.5	20	20.22	6.0	0	94.0	5.88	1.011
	25	25.58	5.4	0	94.6	8.39	1.023

TABLE IV
STATISTICAL ANALYSIS (F-VALUES) OF VARIOUS PARAMETERS

Source	Observed spacing	uniformity	Missing	Number of corms/m length
Nominal spacing (W)	11430.54**	42.96072**	5.613054**	25.08337**
Forward speed (S)	10.65116**	35.57704**	20.26884**	9.638915**
Interaction (W x S)	3.038760*	3.927493**	0.3667444NS	0.6388750NS

**highly significant at P≤0.05, NS – not significant

A. Corm Spacing along the Row

Actual spacing between individual corms dropped in rows was measured during field test for all the three levels of nominal corm spacing and four levels of forward speed. The data was measured from each planted row. The result of the same is presented in Table II. The result indicated that the observed spacing was quite close to the required nominal spacing of the corms. The highest deviation from the mean spacing and coefficient of variation was observed as 3.53 cm and 13.88% respectively. The data also indicated that the deviation increased with the increase in nominal corm spacing and forward speed of operation. This may be due to the skidding of the drive wheel transmitting power to metering units. However, the coefficient of variation was found to increase with increase in forward speed but decreased with increase in nominal corm spacing. The lower value of PREC (<10%) also indicated better uniformity in corm spacing (Table III). A value of less than 10% has been suggested for PREC [3]. Similarly the value of ratio of mean to nominal spacing (Table III) was also observed close the one which indicated that the observed spacing is very close to the required nominal spacing [4].

B. Coefficient of Uniformity

The relationship between forward speed and coefficient of uniformity has been illustrated in Fig. 2, which indicated higher coefficient of uniformity for higher corm to corm spacing at lower speed of operation. The maximum coefficient of uniformity of 97.21% was observed for a nominal corm spacing of 25 cm at 1 km/h forward speed. The uniformity coefficient was found minimum as 87.53% for corm spacing of 15 cm at 2.5 km/h forward speed. This may be due to the fact that the planter movement was observed more uniform at lower forward speed with minimum vibration compared to higher speeds. Another reason for higher coefficient of uniformity at lower forward speed and wider spacing may be due to the fact that the cups of metering device gets sufficient time for self filling and vice versa. The statistical analysis (Table IV) showed significant effect of nominal spacing and forward speed of operation on coefficient of uniformity at 5 percent significance level.

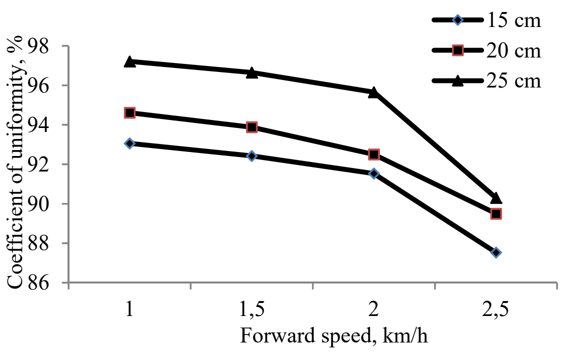

Fig. 2 Coefficient of uniformity as affected by forward speed

C. Missing Percentage

The MISS percentage for all the three levels of nominal spacing and 4 levels of forward speed of operations were determined from a 5 meter long test segment selected randomly from each row. The result (Table III) indicated that MISS percentage was low for lower speed of operation and higher nominal spacing. The finding was in accordance with the findings of previous researchers [3], [6]. On an average, the MISS percentage was observed as 2.55, 3.45, and 4.45% for nominal corm spacing of 25, 20, and 15 cm. The same was observed as 1.53, 2.20, 3.87, and 6.33% for 1.0, 1.5, 2.0, and

2.5 km/h forward speeds respectively. The reason for less missing percentage of corms at wider spacing and lower speed of operation could be due to more time available for self filling of the cups of metering device as compared to lower corm to corm spacing and higher speed of operation as illustrated in Fig. 3. Also at lower speed of operation the vibration could be less in the planter resulting in lesser missing. The result of statistical analysis indicated significant effect of nominal spacing and forward speed on missing percentage at 5 percent significance level. However, the interaction terms of both the parameters was observed not significant (Table IV).

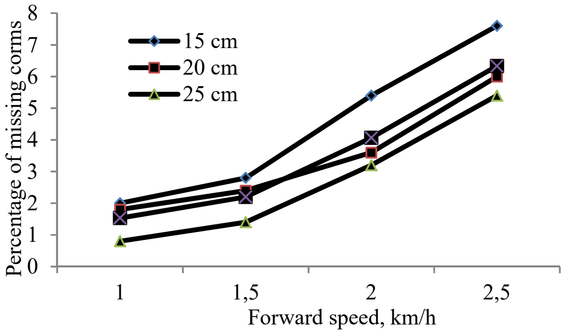

Fig. 3 Missing as affected by speed of operation

D.Multiple Index

The multiple index for all the levels of corm spacing and forward speed of operation was found zero. This means that none of the corms was dropped at spacing ≤ 0.5 times the nominal spacing i.e. closer than the required (Table III).

E. Quality of Feed Index

The QFI was determined for all the levels of forward speed and nominal spacing (Table III). QFI was observed to range between 92.4 and 99.2 percent. The average QFI for 15 cm nominal corm spacing at forward speeds of 1, 1.5, 2 and 2.5 km/h was observed as 95.6%. The same for 20 and 25 cm nominal spacing at forward speeds of 1, 1.5, 2 and 2.5 km/h was observed as 96.55 and 97.45% respectively. The value of QFI was observed higher for low forward speeds and wider nominal spacing. The reason for higher QFI is due to less MISS and no MULT indexes. The acceptable limit of QFI has been suggested as ≥85% for precision seeders [3]. The observed minimum value of QFI is much higher than the suggested limit which shows that ≥92 of every 100 drops were a single corm.

F. Number of Corm per Meter Length

The number of corms per meter length was observed for all levels of corm spacing and forward speed of operation (Fig. 4). The number of corms per meter length was observed as per the theoretical requirement for lower speeds of 1.0 and 1.5 km/h for all the three nominal spacing. However, it was observed less with the increase in speed of operation beyond 2 km/h which is due to higher missing percentage. The result suggested operational speed of planter between 1.0-1.5 km/h for its better performance. The statistical analysis (Table IV) showed significant effect of nominal spacing and forward speed at 5 percent significance level, however, the interaction terms were observed not significant.

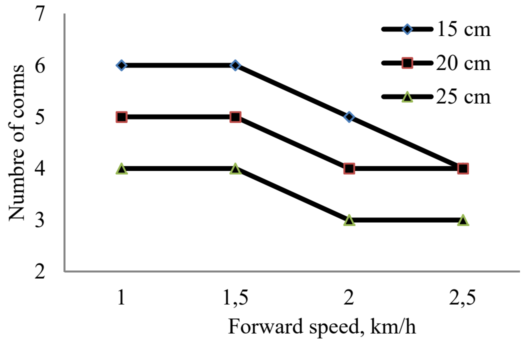

Fig. 4 Number of corms per meter length

G.Mechanical Damage

Fig. 5 indicated higher visible mechanical damage with the increase in forward speed of operation and nominal corm spacing and vice-versa. The maximum visible damage was observed as 1.48% for 15 cm nominal spacing at 2.5 km/h forward speed. This may be due to the fact that at higher speed corms could not fit into the cell of metering unit due to less available time and also due to accumulation of the corms at the bottom of the hopper leading to higher damage of the corms. However, the visible mechanical damage was observed within the acceptable limit of 5%.

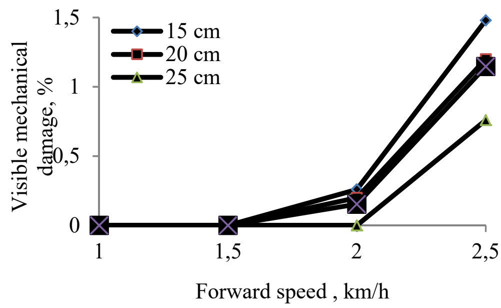

Fig. 5 Relationship between visible mechanical damage and speed of operation

H.Other Performance Parameters

After the field test, the gladiolus planter was operated at 1.10 km/h forward speed for determining other machine parameters. The average field capacity of the planter was observed as 0.103 ha/h with an observed field efficiency of 76.57%. Average draft requirement of the planter was found as 346.52 kgf. The fuel consumption of the planter was observed as 4.14 lit/h.

IV. Conclusion

Based on the field test, it could be concluded that the planter should be operated at forward speed between 1-1.5 km/h for its satisfactory operation. In addition, the lower speed has given minimum variation in corm spacing. The result also indicated that the planter is more suitable for wider nominal spacing as indicated by its lower coefficient of variation. The coefficient of variation was also found higher for higher forward speed and lower nominal spacing. The average field capacity of the planter was found as 0.103 ha/h with field efficiency of 76.57%.

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