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Yogesh Kumar Kosariya
Department of Farm Machinery and Power Engineering, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, India

Surendra Jogdand
Department of Farm Machinery and Power Engineering, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, India

Virendra Manish Victor
Department of Farm Machinery and Power Engineering, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, India

Corresponding Author:
Yogesh Kumar Kosariya
Department of Farm Machinery and Power Engineering, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, India

Effect of machine parameters on the performance of cup-type metering mechanism of developed potato planter cum fertilizer applicator

Yogesh Kumar Kosariya, Surendra Jogdand and Virendra Manish Victor

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Abstract
The present investigation was carried out at research farm of IGKV, Raipur, Chhattisgarh in the year 2018-19 and 2019-20. This experiment was carried out to optimize the following design and operational parameters. Planting material; three size of potato tubers (Round, oblong and long-oblong), independent parameters; Peripheral speeds (V_1, V_2, V_3), Drive wheels used (W_1, W_2, W_3), Angle of furrow opener (S_1, S_2, S_3), Dependent variables; Single percentage, Double percentage, Multiple percentage, Missing percentage, Damage percentage. The combined effect of peripheral speeds, angles of shovel and drive wheel sizes on seed rate for all round, oblong and long-oblong shapes were observed. The averages missing percentage for round shapes were varied from 1.49 to 2.02 %. Minimum missing percentage were observed as 1.49±0.07 % ($V_1S_2W_1$ or in T_1), 1.65±0.09 % ($V_2S_1W_3$ or in T_2) and 2.02 % ($V_3S_3W_3$ or in T_3). Damage percentage for round shapes was found minimum in T_2 or $V_2S_2W_1$ (0.92±0.15%) followed by T_1 or $V_1S_2W_1$ (1.30±0.23 %) and T_3 or $V_3S_1W_2$ (1.50±0.20%) respectively. The average ranges of damage percentage were 1.30 % to 1.63 %, 0.92 % to 1.05 % and 1.50 % to 1.75 % respectively. The average values of missing percentage for oblong shapes were found minimum in treatment combination $V_1S_2W_1$ or T_1 (1.28±0.05 %) followed by $V_2S_2W_1$ or T_2 (1.79±0.01 %) and $V_3S_1W_2$ or T_3 (2.08±0.21 %). The maximum damage percentage for oblong shapes were found in treatment combination $V_3S_1W_2$ or in T_3 (1.82±0.06 %) followed by $V_2S_3W_2$ or T_2 (1.64±0.13 %) and $V_1S_2W_2$ or T_1 (1.44±0.28 %) respectively. It was observed that lowest missing percentages for long-oblong shapes were found in case of treatment combination $V_1S_2W_1$ or T_1 (1.56±0.11%) followed by $V_2S_2W_2$ or T_2 (1.93±0.09%) and highest % missing were obtained with $V_3S_3W_2$ or T_3 (2.28±0.17%) respectively. The lowest damage percentage for long-oblong shapes was found in case of treatment combination $V_1S_2W_1$ or T_1 (1.30±0.17%) followed by $V_2S_3W_1$ or T_2 (1.69±0.27 %). The highest tuber damage percentage was found with $V_3S_1W_3$ or T_3 as 1.92±0.11 % comparatively.

Keywords: Maximum single, Missing percentage, parameters, bund maker, shovel, potato planter

Introduction
Potatoes are grown in almost every state in India. India's major potato-growing states include Uttar Pradesh, West Bengal, Punjab, Karnataka, Assam, Bihar, Madhya Pradesh, Jharkhand, and Chhattisgarh. For planting of potato crop land is furrowed proximately and develop double cross with roto cultivator at a profundity of 24-25 cm depth. Mechanical potato planting performs the functions of furrow opening, seed metering, tuber placement at proper depth and formation of ridges to cover seed tubers. Two, three or four row semi-automatic potato planters have been developed, commercialized and are being used by the largescale farmers. The capacity of such machine is low because of slow speed of operation as feeding of potato is done manually. Automatic potato planters with picker wheel type mechanism are commercially available. They have higher missed with non-graded seeds and result in slippage of tubers when held by actuating finger. The two mechanical potato planters are; *Semi-automatic potato planters*: Tractor drawn three rows and four row planters having rotating cups. The seeds are filled in the container. There is an opening at the lower part of seed container and a solitary layer of potatoes is accessible on the base box. The administrator sits on the seat and picks small bunch of potatoes from the seed container by two hands and drop single potatoes in the cups in the rotational metering plate separated in areas/cups.

The metering plate is pivoted by ground wheel through power transmission framework comprising of sprocket, chain, and cage wheels. (Misener, 1979) [16]. *Automatic potato planter*: Automatic potato planter has rotating picker wheels fixed on one of each side of seed hopper. The picker wheel pivots with the revolution of ground wheel. The cam worked picker arms pick the seed from the seed hopper and drop them into seed pipe. The seeds further fall in the furrow in the edge. Seed spacings are depend on the range of the wheel size. There are normally three column or four row commercial potato planters accessible in India (Misener, 1979) [16]. In many parts of India, large holding farmers now have tractor-operated 3-row or 4-row potato planters for their enormous fields. Those planter's effective field capacity ranges from 0.4 to 0.5 ha/h, with an operating speed of 2.5 to 3.0 km/h and a field efficiency of 75 to 80% whereas there is no good provision of mechanization-based potato planting for small farmers in local areas of the different states.

Materials and Methods

An experimental set up was built to optimize the design and operational parameters of potato tuber cup-metering unit. Experiment was carried out to optimize the following design and operational parameters. Planting material; Size of potato tubers- III (Round, oblong and long-oblong), Metering cup parameter; Cup size-I, independent parameters; Peripheral speed of planter (V)- III, Different drive wheels type (W)- III, Angle of shovel (S, furrow opener sizes)- III, Dependent variables; Single percentage, Double percentage, Multiple percentage, Missing percentage, Damage percentage. So, the combine effect of independent parameters i.e., a) different peripheral speeds V_1 (1.5 km/h), V_2 (2.0 km/h), V_3 (2.5 km/h); different angle of shoe type furrow openers S_1 (45°), S_2 (90°) and S_3 (120°) depicted in Fig. 1 and different drive wheel sizes i.e., W_1(38cm), W_2(42cm) and W_3(52cm) (Fig. 2) on the dependent parameters as performance of metering unit in terms of i) percentage singles, ii) percentage doubles, iii) percentage multiples, iv) percentage missing's and v) percentage damages were studied, discussed for each selected shapes of potato tubers and described below; All the combined parameters in the form of various treatments with three replications were statistically examined to optimization of independent parameters on dependent variables for all the three categories of potato tuber as medium or round, oblong tubers and long-oblong shapes. The criteria selected for the optimum combination of above parameters was, which would yield minimum missing, maximum singles, minimum doubles, and minimum multiples with fewer damages. We can pull the planter with pair of bullocks or with 18-22HP small tractor. Furrow openers are detachable and replaceable. Name of various components (Fig.4) of metering unit of planter are 1. Potato bracket cups 2. Drive wheel 3. Upper gear of seed metering 4. Steel ball bearing 5. First gear used for fertilizer metering unit 7. Second gear of fertilizer metering unit 8. Fertilizer metering shaft 9. Fertilizer metering chain 10. Fluted roller and shaft 6. Tuber seed metering speed steel k-1 attachment chain.

Fig 1: 45°,90° and 120° furrow opener

Fig 2: Drive wheels

Fig 3: View of planter

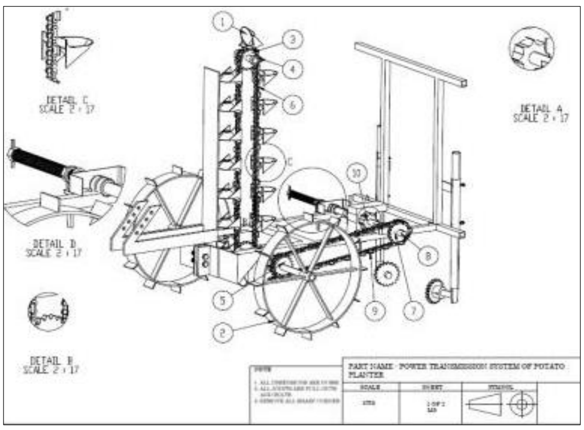

Fig 4: Metering mechanism

Results and Discussion

Laboratory calibrations of planter

The newly developed animal operated automatic feed potato planter with fertilizer application was tested in the laboratory as well as field, to evaluate its performance. Laboratory calibration of seed rate for round seeds was calculated. The ranges of seed rate for round seeds under different treatment were varied from 2613.54±81.77 kg/ha to 1279.24±104.03 kg/ha (Fig. 5). The higher seed rate was found in treatment T_1, in treatment combination of $V_1S_1W_1$ (2613.54 kg/ha) whereas the lowest seed rate was found in T_2 treatment combination $V_2S_2W_3$ (1279.24 kg/ha) due to the larger spacing with wheel type W_3 the seed rate was reduced. It was observed that the seed rate was decreased with increase in speed and with increased diameter of wheel due to reduction in exposure time of cell to seeds. The seed rate was found minimum with using larger drive wheel with increased speed (T_3) than the lower drive wheel diameter with higher speed (T_1). Optimum seed rate was found in treatment $V_1S_2W_1$ (2473.62 kg/ha) which are closed to the recommended seed rate of potato tubers. Laboratory calibration of seed rate for oblong seeds was calculated. The ranges of seed rate for round seeds under different treatment were varied from 1244.87±34.04 kg/ha to 2616.54±111.81 kg/ha. It was inferred that, the peripheral speed, angle of shovel and wheel diameters had highly significant at one % level on seed rates. The higher seed rate for oblong shapes was found in treatment T_1, in treatment combination of $V_1S_1W_1$ (2616.77 kg/ha) whereas the lowest seed rate was found in T_3 treatment combination $V_3S_3W_3$ (1244.87 kg/ha) due to the larger spacing with wheel type W_3 the seed rate was reduced. Laboratory calibration of seed rate for long-oblong seeds was calculated. The ranges of seed rate for round seeds under different treatment were varied from 1244.87±34.04 kg/ha to 2616.54±111.81 kg/ha. It was inferred that, the peripheral speed, angle of shovel and wheel diameters had highly significant effect on seed rates at 1 % level. The higher seed rate for long-oblong shapes was found in treatment T_1, in treatment combination of $V_1S_1W_1$ (2306.14 kg/ha) whereas the lowest seed rate was found in T_3 treatment combination $V_3S_3W_3$ (1104.55 kg/ha) due to the larger spacing with wheel type W_3 the seed rate was reduced.

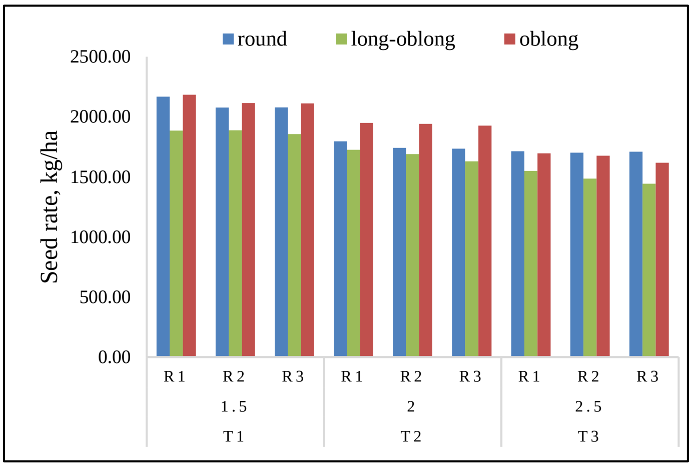

Fig 5: Seed rates of round, oblong and long-oblong tubers during laboratory calibration of planter

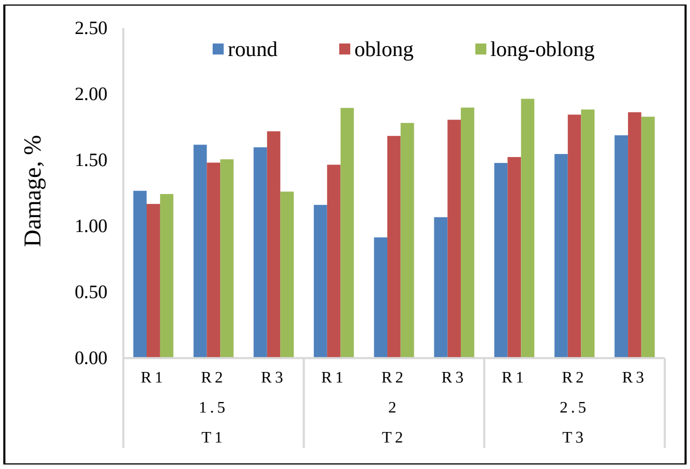

Fig 6: Damage percentage under different treatments for all the shapes in laboratory calibration

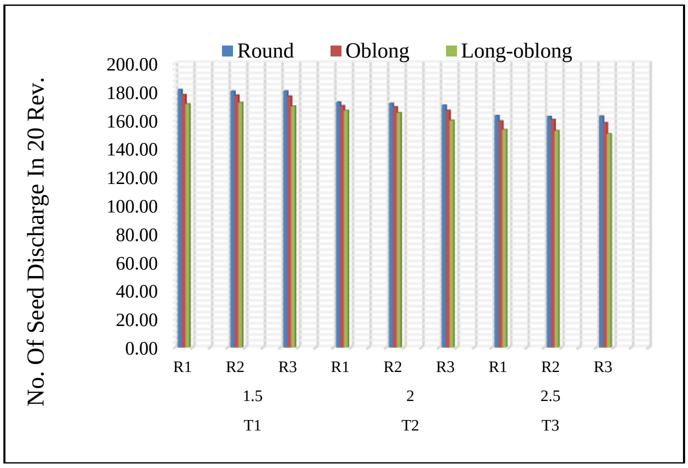

Fig 7: Seed distribution test under different treatments for all shapes in the laboratory

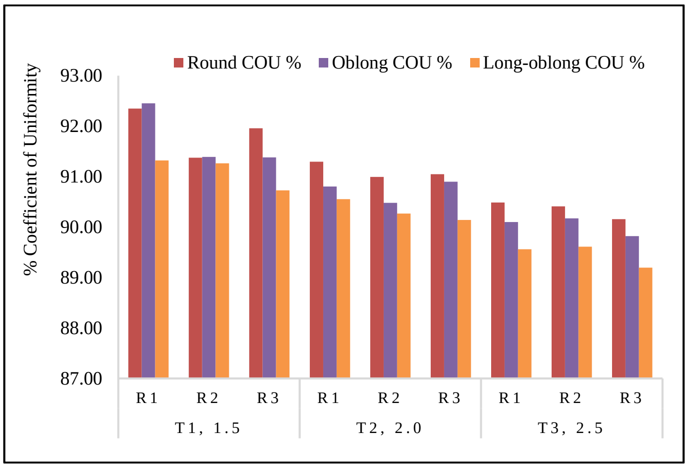

Fig 8: Percent coefficient of uniformity under different treatments for round, oblong and long-oblong tubers

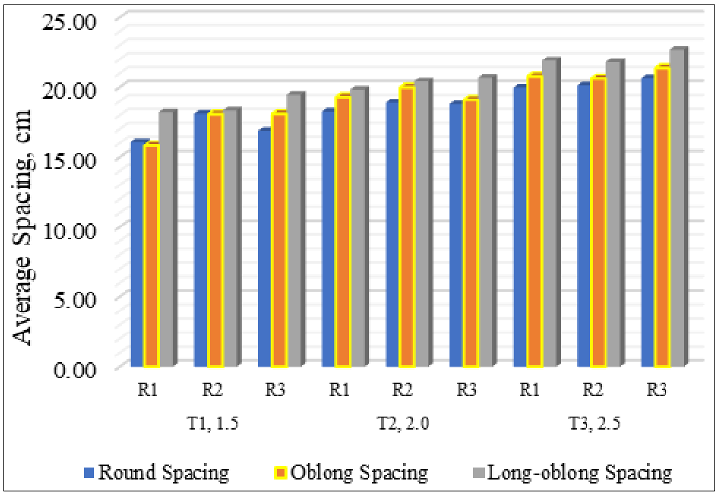

Fig 9: Average spacing between two seeds for round, oblong and long-oblong tubers

Fertilizer rate

Fertilizer rate can be calculated from the delivery of fertilizer in twenty number of revolutions for all the types of ground wheel used in the laboratory as well as field. The single row automatic feed potato planter with fertilizer metering mechanism was tested in the field to determine the placement depth and rate of fertilizer. The placement of fertilizer requires prior to seed placement. The average depth of fertilizer placement was found to 20cm as per potato seeds dropped by the planter. The ranges of fertilizer calibration were varying from lowest $V_3S_1W_3$ (22.77±1.26 kg/ha) to highest $V_1S_2W_1$ (47.23±0.88 kg/ha) under different treatment. Highest rate was found in treatment T_1 (47.23 kg/ha) followed by $V_2S_1W_1$ or T_2 (41.72±0.63 kg/ha) and T_3 (22.77±1.26 kg/ha). It was observed that when peripheral speed increased from 1.5km/h (V_1) to 2 km/h (V_2), the fertilizer rate decreased. Further when the peripheral speed increased from 2km/h (V_2) to 2.5km/h (V_3) km/h with an increment of 0.5 km/h speed the rate of fertilizer decreased again with larger spacing.

Mechanical damage

The mechanical damage of seed was occurred due to higher peripheral velocity of chain and sprockets and sharp edges of the machine. In the developed prototype keeping in mind these limitations the machine was designed smoothly so that as less as the damage percentage was found. The damage effect of different speed on the all-seed type selected was observed and it was almost like the mechanical damage of all the seed but found maximum for the larger shapes with respect to the round shapes. The percentage mechanical damage of all the seeds was slightly increased with speed (Fig. 6). At the speed 1.5 km/h, 2.0 km/h and 2.5 km/h, the damage % were observed as 1.49, 1.50 and 1.57 % for round shapes for oblong tubers it was 1.46, 1.65 and 1.74 % which are slightly higher than round tubers and for long-oblong tubers % damage at different speed was 1.34, 1.86 and 1.89 %. The damage percentage at speed 2.5kmph were observed slightly higher than the lower speed but within the permissible limit of 2 %.

Seed distribution

The length of the strip at different speed for twenty revolutions of different drive wheels used as W_1 (38cm), W_2 (42cm) and W_3 (52cm) with all the shovels (45°, 90° and 120°) was calculated as 23.87 m, 26.38 m, and 32.67 m. The number of seed discharge from the furrow with these drive wheels was also tested and observed their performance among the all rows. Average number of maximum seed was distribution observed with the drive wheel W_1(38cm) followed by W_2(42cm) and W_3(52cm). The number of seed discharge was decreased with the increment of speed from 1.5 to 2.5 km/h. The ranges of number of seed discharged in twenty revolution of ground wheel at different speed was varied from 158.33±2.08 to 183.33±4.16 for round shape tubers, 153.67±1.53 to 180±2.0 for oblong shapes and 147.67±1.53 to 175.0±2.65 for long-oblong tubers respectively (Fig. 7). Treatment combination $V_1S_1W_1$ was found significant maximum seed discharged for all the shapes of tubers whereas treatment combination $V_3S_3W_3$ gives lowest number of seed discharge due to the larger wheel size and higher speed of the power transmission wheel.

Seed uniformity test

To determine the uniformity of placement of seed within the row, the distance between two consecutive seeds measured with laboratory sand bed test. The coefficient of uniformity was inversely proportional to the spacing of seeds. The average spacing between two consecutive seed and coefficient of uniformity varied from 13.87 to 21.70 cm for round seed, 14.63 to 22.67 cm for oblong shapes and 16.40 to 23.90 cm (Fig. 9) against the recommended spacing 20 cm and their resulting coefficient of uniformity was varied as 93.40% to 89.67%, 93.03% to 89.21% and 92.19% to 88.62% respectively (Fig. 8). These values were closer to recommend value suggested by crop specialists. Santos & Rodriguez (2008) revealed that the spacing between two consecutive seed should be 20 cm. Seed uniformity % decreased as the speed increased due to larger spacing between the seeds and were highest in T_1 (93.40%) followed by T_2 (92.24%) and T_3 (91.51%) for round shapes and for oblong shapes T_1 (93.03%) followed by T_2 (91.40%) and T_3 (89.35%) further it was T_1 (92.19%) followed by T_2 (89.59%) and T_3 (88.62%) respectively.

Performance of cup-chain metering mechanism in terms of singles, doubles, multiples, missing and damage percentages for round shapes

The ranges of average percentage single vary from 83.32 to 88.63 under different treatment. Highest single percentage was found in treatment T_1 or $V_1S_2W_1$ (88.39±1.09 %) followed by T_2 or $V_2S_1W_3$ (85.60±0.48 %) and T_3 or $V_3S_1W_1$ (83.59±0.48 %) with a coefficient of variation of 1.05 %, 1.24 % and 0.58 % respectively. It was observed that when peripheral speed increased from 1.5km/h (V_1) to 2 km/h (V_2), the % singles also increased for round shapes. Further when the peripheral speed increased from 2km/h (V_2) to 2.5km/h (V_3) km/h with an increment of 0.5 km/h speed the % singles decreased. From this, it was evident that beyond certain peripheral speed the tuber might be thrown out of the cup which caused reduction in % singles. The ranges of average *percentage doubles* varied from 9.60 to 10.94% under different treatment. Highest double percentage was found in treatment T_1 or $V_1S_2W_1$ (10.94±0.11 %) followed by T_2 or $V_2S_3W_2$ (10.31±0.38 %) and T_3 or $V_3S_1W_3$ (9.74±0.23 %) with a coefficient of variation of 1.05 %, 1.24 % and 0.58 % respectively. It was observed that when peripheral speed increased from 1.5km/h (V_1) to 2 km/h (V_2), the % doubles also decreased. Further when the peripheral speed increased from 2km/h (V_2) to 2.5km/h (V_3) km/h with an increment of 0.5 km/h speed the % doubles decreased. From this, it was evident that beyond certain peripheral speed the tuber might be thrown out of the cup which caused reduction in % doubles.

Table 1: Performance indices of all the shapes

Seeds	Treatment	% Single		% Double		% Multiple		% Missing		% Damage	
		Mean	Sd	Mean	Sd	Mean	Sd	Mean	Sd	Mean	Sd
Round	T_1	88.39	0.21	10.87	0.10	5.95	0.14	1.66	0.16	1.52	0.19
	T_2	85.60	0.12	10.13	0.17	5.46	0.14	1.79	0.12	0.97	0.07
	T_3	83.59	0.36	9.69	0.08	4.77	0.17	1.99	0.06	1.61	0.13
Oblong	T_1	86.89	0.26	9.68	0.08	4.56	0.17	1.36	0.14	1.32	0.18
	T_2	84.48	0.89	9.06	0.37	3.85	0.13	1.69	0.18	1.55	0.15
	T_3	82.85	0.16	8.41	0.30	3.71	0.04	2.13	0.06	1.68	0.21
Long-oblong	T_1	86.03	0.15	8.43	0.06	3.47	0.07	1.65	0.08	1.15	0.15
	T_2	83.46	0.74	7.96	0.10	3.26	0.26	2.02	0.12	1.75	0.10
	T_3	82.53	0.34	7.61	0.06	2.94	0.12	2.16	0.14	1.85	0.09

Multiple percentage under different treatments for round seed at different speeds, shovel angles and with drive wheels. It was found that maximum multiple percentage (Table 1) were in 1.5 km/h due to the lower speed that keeps the smooth working of metering mechanism, since the dropping rate of seed was highest as compared to other. Hence seed to seed spacing was reduced. Multiple percentage were observed highest in treatment T_1 or $V_1S_2W_3$ (6.06±0.26%) at 1.5km/h whereas T_2 or $V_2S_1W_2$ (5.61±0.05%) and T_3 or $V_3S_3W_3$ (4.89±0.10%) at 2.0 and 2.5 km/h respectively with a coefficient of variation of 4.22, 0.83 and 2.09 %. *Percentage of missing* for round shapes slightly increases as speed increase. Percentage of missing also affected by the size of the cups, metering mechanism quality and operational speed of the planter. Percentage missing was less as compared to singles and doubles. The averages missing percentage was varied from 1.49 to 2.02 %. Minimum missing percentage were observed as 1.49±0.07 ($V_1S_2W_1$ or T_1) at a speed of 1.5 km/h, 1.65±0.09 ($V_2S_1W_3$ or T_2) % at 2.0 km/h and 2.0 % at 2.5 km/h ($V_3S_3W_3$ or T_3). It was further observed that when the size of drive wheels increased, % missing was also increased. This was due to larger wheels delivers the tubers at larger distances and higher speed reduces the cell filling performance due to vibration. To overcome tuber damage in the all zones i.e., tuber container, cup to cup distance on the chain, falling angle of the tubers, free fall height was minimized in newly developed machine. The overall percentage damage of round seeds at speed of 1.5 km/h, 2.0 km/h and 2.5 km/h were observed and found minimum in case of T_2 or $V_2S_2W_1$ (0.92±0.15%) at speed of 2.0 km/h followed by T_1 or $V_1S_2W_1$ (1.30±0.23%) at 1.5 km/h T_3 or $V_3S_1W_2$ (1.50±0.20%) respectively with the coefficient of variation of 16.80, 17.94 and 12.99%. In case of other selected shapes, which are also within the permissible limit of 2 %. The damage percentage at speed 2.5 km/h were observed slightly higher than the lower speed. The average ranges of percentage damage for speed 1.5kmph, 2.0kmph and 2.5kmph was 1.30 to 1.63, 0.92 to 1.05 and 1.50 to 1.75 respectively for round shapes which are also within the permissible limit.

Performance of cup-chain metering mechanism in terms of singles, doubles, multiples, missing and damage percentages for oblong shapes

Percentage of singles was affected by the speed of operation of the potato planter. Percentage of singles and doubles slightly decreased with speed increased for oblong shapes. Average ranges for oblong shape tubers varied from 86.64 to 87.16 % for T_1, 83.61 to 85.39 % in T_2 and 82.73 to 83.03 % in case of T_3 and it was observed highest in treatment combination $V_1S_2W_1$ or T_1 (87.16±0.61%) followed by $V_2S_1W_2$ or T_2 (85.39±0.71%) and $V_3S_2W_2$ or T_3 (83.03±0.41%) respectively with a CV % of 0.70, 0.84 and 0.49. It was observed that, all the drive wheel sizes, peripheral speeds and angles of shovel performs highly significant at level of five % on % singles. The average ranges in of *percentage double* in Table. 1 for oblong shapes were varied from 9.61 to 9.76% (T_1), 8.70 to 9.44 % (T_2) and 8.18 to 8.75 % (T_3). It was observed that higher percentage of doubles was maximum with treatment combination T_1 or $V_1S_3W_2$ (9.76±0.22%) followed by T_2 or $V_2S_1W_3$ (9.44±0.25%) and T_3 or $V_3S_3W_3$ (8.75±0.03%) with a coefficient of variation of 2.29, 2.66 and 0.29 % respectively. It was indication that when peripheral speed increased from 1.5 (V1) to 2.0 (V2) km/h, the % doubles decreased. Further when the speed increased from 2.0km/h percentage doubles also increased for oblong shapes. From this, it was clear that, at lower peripheral speed the potato tubers were held in the cups which contributed for higher % doubles. It was further observed that when the drive wheel size increased, % doubles decreased due to vibration inside the hopper and this might be due to, cups in vertical position was opposite to the gravitational force of the oblong potato tubers. It was inferred that, combination of peripheral speeds, angles of shovel and drive wheels had significant at five % level on doubles. It was observed that when peripheral speed increased from 1.5 (V_1) to 2.0 (V_2) km/h, the *per cent multiples* for oblong shape decreased. The reason might be, higher peripheral speed would have made the potato tubers to fall from the metering cups. It was further observed that when the size of the drive wheel increased, % multiples decreased. This was due to gravitational force produced inside the hopper during operation. The average multiple % for oblong shapes, ranges were varied from 4.37

to 4.70% (T_1), 3.75 to 4.0% (T_2) and 3.66 to 3.74% (T_3). The highest multiple % were observed in case of treatment combination T_1 or $V_1S_1W_2$ (4.70±0.25%) due to the lowest speed as V_1 (1.5 km/h) followed by T_2 or $V_2S_2W_3$ (4.0±0.21%) and T_3 or $V_3S_1W_1$ (3.74±0.15%) with a coefficient of variation of 5.39%, 5.13% and 4.09% respectively. It was inferred that, all the peripheral speeds, angles of shovel and drive wheels had highly significant at five % level on multiple percentage. It was observed that when peripheral speed increased from 1.5 (V_1) to 2.0 (V_2) km/h, the *per cent missing* increased. Further when speed increased from 2.0 (V_2) km/h to 2.5 (V_3) km/h, the per cent missing again increased. At higher peripheral speed of metering unit, cups were unable to hold the potato tubers. This might have caused higher % missing at higher peripheral speed. It was observed that when the size of the drive wheel increased, % missing increased again. This might be due to larger the wheel diameter causes decreased the probability of holding capacity of cups at higher speed. The average values of missing percentage under different treatment were varied from 1.28 to 1.52% (T_1), 1.48 to 1.81% (T_2) and 2.08 to 2.19% for T_3 respectively. Missing percentage was found minimum in case of treatment combination $V_1S_2W_1$ or T_1 (1.28±0.05 %) followed by $V_2S_2W_1$ or T_2 (1.79±0.01 %) and $V_3S_1W_2$ or T_3 (2.08±0.21 %) with a CV % of 4.08, 0.66 and 9.92 % respectively. It was observed that when peripheral speed increased from 1.5 (V1) to 2.0 (V2) km/h, the *percent tuber damage* increased slightly. It was also further observed that when the angle of furrow opener increased, % bulb damage increased. The maximum damage percentage was found in treatment combination $V_3S_1W_2$ or T_3 (1.82±0.06 %) followed by $V_2S_3W_2$ or T_2 (1.64±0.13 %) and $V_1S_2W_2$ or T_1 (1.44±0.28 %) respectively with CV of 3.12 %, 7.95 % and 19.15 %. The average ranges of damage percentage varied from 1.12 to 1.44 % (T_1), 1.38 to 1.64 % (T_2) and 1.43 to 1.82 % (T_3).

Performance of cup-chain metering mechanism in terms of singles, doubles, multiples, missing and damage percentages for long-oblong shapes

It was observed that when peripheral speed increased from 1.5 (V_1) to 2.0 km/h (V_2), the *per cent singles* also increased for long-oblong shape. Further when the peripheral speed increased from 2.0 (V_2) to 2.5 (V_3) km/h with an increment of 0.5 km/h speed the % singles decreased. From this it was evident that beyond certain peripheral speed the potato tubers might be thrown out of the cup which caste reduction in % singles. It was further observed that when the diameter of drive wheel increased, % singles also increased. From the results of variance obtained it was inferred that, all the peripheral speeds and angles of shovel and drive wheel sizes had highly significant at five % level on single percentage. It was observed that at speed 2.0 (V_1) km/h with the 42cm (W_2) drive wheel had the highest per cent singles. The lowest per cent singles were found in treatment combination $V_3S_3W_3$ or T_3. So, it was also observed that the treatment combination $V_1S_1W_2$ or T_1 had the highest % of singles (86.16 %) and treatment combination $V_3S_3W_3$ (82.76 %) had the lowest % singles and were at par. It was observed that when peripheral speed increased from 1.5 (V_1) to 2.0 (V_2) km/h, the *per cent doubles* decreased. From this, it was clear that, at lower peripheral speed the potato tubers were held in the cups which contributed for higher per cent doubles. It was further observed that when the drive wheel size increased, % doubles decreased. This might be due to; it takes larger travelling distance that reduces the percentage double values. It was observed that treatment combination $V_3S_2W_1$ or T_3 (7.54%) had the lowest per cent doubles followed by $V_2S_3W_1$ or T_2 (7.96%). The highest per cent doubles for long-oblong shapes were found in $V_1S_2W_1$ or T_1 (8.49%). It was observed that when peripheral speed increased from 1.5 (V1) to 2.0 (V2) km/h, the % multiples decreased (Table. 1). The reason might be, higher peripheral speed would have made the tubers to fall from the cups. It was further observed that when, with the drive wheel size increased and angle of furrow opener decreased, *per cent multiples* decreased. This was due to lower angle of shovel delivers one or two seeds only at same time. Higher peripheral velocity of chain decreases the multiple percentage. The lowest multiple percentage was found in case of treatment combination $V_3S_2W_1$ or T_3 (3.05%) followed by $V_2S_1W_2$ or T_2 (3.45%) and $V_1S_2W_2$ or T_1 (3.52%) respectively. It was distinguished that when peripheral speed increased from 1.5 (V_1) to 2.0 (V_2) km/h, the *per cent missing* increased. At higher peripheral speed of metering unit, cups were unable to hold the long-oblong shape tubers. This might have caused higher % missing at higher peripheral speed. It was further observed that when the wheel size increased, per cent missing increased. This might be due to larger delivered spacing between seed to seed. It was inferred that, all the peripheral speeds, angles of shovel and size of drive wheels had highly significant effect at five % level on missing. It was observed that lowest % missing was found in case of treatment combination $V_1S_2W_1$ or T_1 (1.56±0.11%) followed by $V_2S_2W_2$ or T_2 (1.93±0.09%) and highest % missing was obtained with $V_3S_3W_2$ or T_3 (2.28±0.17%) respectively. When peripheral speed increased from 1.5 ($V_{1)}$ to 2.5 (V_3) km/h, the *per cent damage* for long-oblong shapes was increased. The lowest tuber damage was found in case of treatment combination $V_1S_2W_1$ or T_1 (1.30±0.17%) followed by $V_2S_3W_1$ or T_2 (1.69±0.27%). The highest tuber damage percentage was found with $V_3S_1W_3$ or T_3 as 1.92±0.11 % comparatively.

Conclusion

Animal or small tractor were easily capable to pull the developed potato planter cum fertilizer applicator as per the draft requirement. The draft requirement for developed planter was 72.84 kgf in clods and gives satisfactory performance i.e., the developed unit has appropriate seed to seed spacing, row spacing, minimum doubles, minimum multiples, minimum missing, minimum damages, and maximum singles with chosen depth. Based on selected criteria for design and fabrication of machine the treatment combination $V_1S_2W_1$ and $V_2S_2W_2$ was used for planter development and application. So, all the field evaluations were based on these selected combinations.

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