RESEARCH ARTICLE

Effect of the Machine Parameters on Field Performance of Developed Potato Planter Cum Fertilizer Applicator

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Abstract

The field experiment, conducted at the instructional farm of Indira Gandhi Krishi Vishwavidyalaya Raipur in the year 2019-20, was laid out in factorial randomized block design for potato planting by newly developed potato planter cum fertilizer applicator with various machine parameters as 3 main plot (different speeds as V_1 or 1.5 km/h, V_2 or 2.0 km/h and V_3 or 2.5 km/h) and 3 subplots (different drive wheel diameter i.e., W_1 or 38 cm, W_2 or 42 cm, W_3 or 52 cm) are made. Subplots also divided in 3 separate plots (Different shovel angle as S_1 or 45°, S_2 or 90° and S_3 or 120°) for each subplot. The effect of the combination of these independent parameters on dependent parameters (single, double, multiple, missing and damage percentage) was observed in the developed potato planter's performance. The average germination percentage of potato seed was recorded as round (86.4%), oblong (81.6%) and long-oblong (79.6%) for unmetered planted seeds. For the metered seeds, germination percentage was found as round (81.3%), oblong (79.4%) and (78.4%), respectively. Maximum theoretical field capacity was found as 0.150 ha/h at the speed 2.5 km/h followed by 0.120 ha/h at the speed of 2.0 km/h and 0.090 ha/h at the speed of 1.5 km/h, respectively. Maximum effective field capacity was observed as 0.106 ± 0.005 ha/h at the speed 2.5 km/h followed by 0.089 ± 0.007 ha/h at the speed of 2.0 km/h and 0.065 ± 0.001 ha/h at the speed of 1.5 km/h, respectively. Maximum average field efficiency was 74.193 % at the speed of 2.0 km/h followed by 72.069 % at speed of 1.5 km/h and 70.704% at speed of 2.5 km/h, respectively. The average draft recorded at the speed of 1.5 km/h, 2.0 km/h and 2.5 km/h were 68.41 ± 1.02 kgf, 70.93 ± 0.97 kgf and 77.15 ± 0.65 kgf, respectively. The average power required for potato planter was recorded as 0.527 ± 0.140 hp.

Keywords: Theoretical field capacity, effective field capacity, field efficiency, seed uniformity, height and width of machine, potato planter, variable speeds

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Introduction

Potato is 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. Mechanical potato planting performs the functions of furrow opening, seed metering, tuber placement at proper depth and formation of ridges to cover seed tubers. Three or four-row semi-automatic and automatic potato planters have been developed, commercialized, and used by phares farmers (Kumar *et al*., 2017). Large-holding farmers in many parts of India now have tractor-operated 3-row or 4-row potato planters for giant fields. Their 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% and there is no good availability of mechanization-based potato growing for small farmers in local areas of the states (Kumar *et al*., 2017). In the manual method of potato planting, farmers cover less area in more time. In manual potato planting methods, the furrow edges are generally made by animal-drawn ridger and seed potatoes are planted manually on lines.

In semi-automatic tractors drawn three-row and four-row planters with rotating cups need one extra man to operate the machine. 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 potatoes from the seed container by two hands and drops single potatoes in the cups in the rotational metering plate separated in cups. The metering plate is pivoted by ground wheel through power transmission framework comprising of sprocket, chain, and cog wheels. (Misener, 1979). In automatic potato planter, it has rotating picker wheels fixed on the sides of seed container. The picker wheel pivots with the revolution of ground wheel. The picker arms pick the seed from the seed container and drop them into seed pipe. Indian agriculture is characterized by small and marginal farm holders with contribution of more than 60 million bovines for draught animal power. The strategy of conventional implements depends on long insight and these have filled the need of the farmers. Nonetheless, there is a lot of degree to further develop the plan dependent on creature machine-climate communication to have more yield and expanded proficiency without imperiling creature wellbeing. Draught animal power and 18 to 25 hp small tractor are the classic example of large-scale application of appropriate technology concepts to millions of small and marginal farmers for cultivation and small-scale transportation.

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Materials and methods

The field experiment, conducted at Indira Gandhi Krishi Vishwavidyalaya Raipur in the year 2019-20, the experiment was laid out in factorial randomized block design for potato planting with developed planter cum fertilizer applicator with various independent parameters as 3 main plot (different speeds as V_1 or 1.5 km/h, V_2 or 2.0 km/h and V_3 or 2.5 km/h) and 3 sub plots (different drive wheel diameter i.e., W_1 or 38 cm, W_2 or 42 cm, W_3 or 52 cm) are made. Subplots also divided in 3 separated plots (Different shovel angle as S_1 or 45°, S_2 or 90° and S_3 or 120°) for each sub plot. The effect of these independent parameters on dependent parameters (single, double, multiple, missing and damage percentage) was observed in terms of machine performance. Resulting 27 different treatment with 3 replications. A combination of these variables was observed and recorded according to their suited condition regarding machine performance. Field preparation was done by tractor-drawn rotavator with two passes to get the proper seedbed for sowing potato seed with the developed planter. The seed and fertilizer were drilled in rows directly as experimental plots by maintaining the row-to-row spacing 60 cm and plant-to-plant distance 15-20 cm for potato seeds (categorized as round, oblong and long-oblong). The shape of field was rectangular and the total area was 56 x 35 m in this field two passes of the rotavator did the seed bed preparation. The soil moisture percent and bulk density were measured by taking the sample from the 2.5 to 20 cm depth. The field had an optimum moisture content of 15.25% on (d.b.) and 11.91% on (w.b.), bulk density (1.69 g/cm^3), average porosity (34.66%), mean mass diameter (11.23mm) and cone index (238.10 kPa) which is adequate for sowing operation. Draft requirement of the developed planter was 72 kgf and the power requirement was less than 1 hp.

Draft and power requirement

Draft requirement can be calculated as; Draft (N) = soil resistance (N/cm^2) × furrow cross section (cm^2). The power required to operate the machine by bullocks with an average pulling force and speed was calculated as;

$$\text{Power(kW)} = \frac{\text{Pulling force (kN)} \times \text{Speed(km/h)}}{3.6} \quad \text{(Singh } et\ al.\text{, 2014)}$$

Seed rate

The seed rate was calculated as per IS-6316-1993 and the procedure was replaced by round tubers, oblong and long-oblong tubers then seed rate kg/ha was determined by using the following relationship;

$$\text{Seed Rate(kg/ha)} = \frac{\text{Weight of seed from all furrow openers in 20 rev.of drive wheel(kg)}}{\text{Area covered in 20 rev.of ground wheel (ha)}}$$

Seed distribution test and mean uniformity

This test was conducted to study furrow-to-furrow variation in seed metering. During calibration, the number of-seeds discharged from 20 revolutions of ground wheel is collected. The total number of seeds collected from each furrow opener were counted.

The mean spacing between the tubers the mean spacing between two tubers is calculated and the average value was found out and the coefficient of uniformity was calculated by following formula

$$\text{COU} = 100 \times (1 - \frac{\sum X - \bar{X}}{N \times \bar{X}}) \quad \text{(Smith } et\ al.\text{, 1994)}$$

Where,
COU = coefficient of seed uniformity
X = spacing between two consecutive seeds
X =Theoretical spacing
N = Total number of seeds in 5m length

Seed germination test

Hundred seeds from each type of tuber were taken randomly from each plot. The sprouts of seeds were observed after sixth day and a number of sprouts was counted daily. The counting of sprouts was stopped when the number remained constant for three consecutive days. The germination percentage was calculated by the following formula;

$$\text{Germination (\%)} = \frac{\text{Number of germinated seeds}}{\text{Total number of seeds taken for test}} \times 100 \qquad \text{ISTA (1996)}$$

Calculation of theoretical field capacity, effective field capacity and field efficiency

The effective field capacity is the average coverage rate, including the time lost in filling the hopper and turning at the end of the rows.

$$\text{Effective field capacity (ha/h)} = \frac{\text{Area of Plot (ha)}}{\text{Time taken (h)}}$$

$$\text{Theoretical field capacity(ha/h)} = \frac{W \times S}{10} \qquad \text{(Verma } et\ al.\text{, 2016)}$$

Where,
W = Width of planter, m
S = Speed of operation, km/h
Field efficiency is the ratio of the effective field capacity to the theoretical field capacity as shown below;

$$E_f = \frac{FC_e}{FC_t} \times 100 \qquad \text{(Verma } et\ al.\text{, 2016)}$$

Machine pull and power

The spring dynamometer (capacity = 100 kgf) was tied between the planter and handle with the help of rope. The observation of pull was recorded during each pass of the planter for 5 replications after calculating the angle of pull the draft was determined.

D = Pxcosθ
Where,
θ = Angle between line of pull and horizontal degree
P = Pull. kgf;
D = Draft, kgf
Power was calculated using the relation given as:
Power,(W) = Draft (N) × Speed (m/s), Smith *et al.* (1994) and Singh *et al.* (2014)

Placement depth, row spacing and height of ridge

After showing, row to row spacing and depth was measured by a 30 cm scale. Five random evaluations were taken within the showed row and the average was determined to represent row-to-row spacing in all treatments. Height and width of the ridge was measured with the help of meter scale at random places in each treatment.

Quality of feed index

This is a measure of how close the spacings are to the theoretical spacing. The quality of feed index was calculated as follows;

QFI,% = 100-(MULTI + MISI) (Al-Gaadi and Marey, 2011)

Results and Discussion

Seed rate for all shapes of potato tuber

The ranges of seed rate for round shapes under different treatments and variables it was varied from 1254.46 kg/ha to 2626.37 kg/ha. The higher seed rate was recorded in the treatment combination of $V_1S_1W_1$ (2626.37 kg/ha) whereas the lowest seed rate was found in treatment combination $V_3S_2W_3$ (1254.46 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 the exposure time of cell to seeds. The seed rate was found minimum with using larger drive wheel with increased speed than the lower drive wheel diameter with higher speed. From the analysis of variance, it was inferred that all the peripheral speeds, shovel and wheel diameters' angles were highly significant at 5% level on seed rates. The ranges of seed rate for oblong seeds under different treatment were varied from 1309 kg/ha to 2604 kg/ha. The higher seed rate for oblong shapes was found in the treatment combination of $V_1S_1W_1$ (2604 kg/ha) whereas the lowest seed rate was recorded in treatment combination $V_3S_3W_3$ (1309 kg/ha) due to the larger spacing with wheel type W_3 the seed rate was reduced. Results of variance obtained on seed rate for oblong seeds under laboratory calibration from that, it was inferred that, the peripheral speed, angle of shovel and wheel diameters had highly significant at 1% level on seed rates. Highest seed rate for long-oblong shape was found in treatment T_1 (1942.42 kg/ha) and lowest in case of T_3 (1538.86 kg/ha). From the analysis of variance, it was inferred that, the peripheral speed, angle of shovel and wheel diameters had a significant effect at 1% level on seed rates. The ranges of seed rate for long-oblong seeds under different treatment were varied from 1172.76 to 2307.69 kg/ha. The higher seed rate for long-oblong shapes was found in the treatment combination of $V_1S_1W_1$ (2307.69 kg/ha), whereas the lowest seed rate was found in treatment combination $V_3S_3W_3$ (1172.76 kg/ha) due to the larger spacing with wheel type W_3 the seed rate was reduced (Fig. 1).

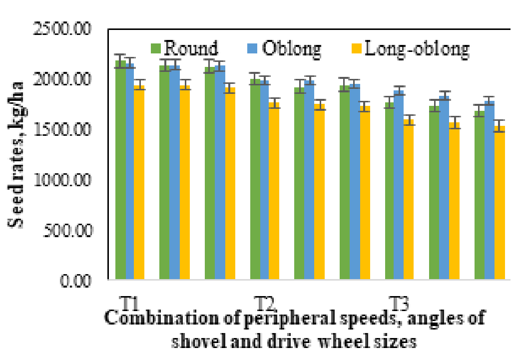

Fig. 1: Seed rates

Fertilizer rate

Fertilizer rate was calculated from the delivery of fertilizer in the given number of revolutions for all the types of variables such as peripheral speed, angle of shovel and drive wheels used in the field. The average depth of fertilizer placement was found to 20 cm as per recommended potato seeds dropped by the planter. Ranges of fertilizer rates varied from lowest $V_3S_1W_3$ (26.01 kg/ha) to highest $V_1S_1W_1$ (52.38 kg/ha) under different treatments. The highest rate was found in treatment T_1 (52.38 kg/ha) followed by T_2 (46.15 kg/ha) and T_3 (26.01 kg/ha). It was observed that when peripheral speed increased from 1.5 km/h to 2 km/h, the fertilizer rate decreased. Further when the peripheral speed increased from 2 km/h (V_2) to 2.5 km/h with an increment of 0.5 km/h speed, the fertilizer rate decreased again with larger spacing. According to results, higher seed rates were obtained with a smaller ground wheel with minimum speed. Dropping fertilizer in the field was found significant with permissible limits under as 70 kg/ha.

Mean spacing and coefficient of uniformity test for all shapes of tuber

The average spacing between two consecutive round seeds were varied from 14.37 to 22.53 cm against the recommended spacing 15 to 20 cm. 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. The seed uniformity percent varied and it slightly decreased with increased speed and larger drive wheel sizes results were highest in T_1 (92.33, 92.08 and 92.17%) followed by T_2 (91.37, 91.08 and 91.18%) and T_3 (90.55, 90.19 and 89.97%) respectively for all of the round seeds (Fig. 2). The average spacing between two consecutive oblong seed varied from 15.49 to 22.89 cm against the recommended spacing 15-25 cm. observation shows that the spacing between two seeds and their resultant uniformity percent which is varied and it

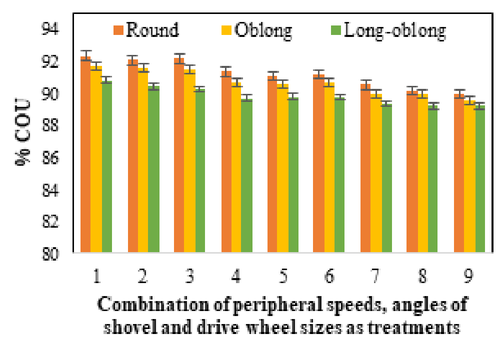

Fig. 2: Coefficient of uniformity

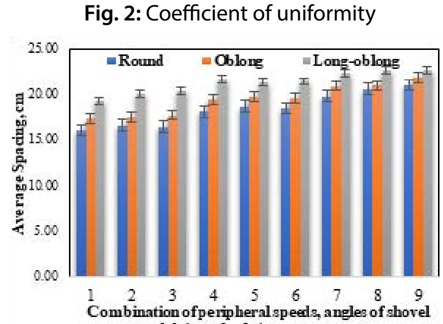

Fig. 3: Mean spacing between two successive seeds

slightly decreased with increased speed and increase wheel sizes. The coefficient of uniformity was highest in treatment combination $V_1S_1W_1$ in T_1 (92.63, 91.60 and 90.97%) followed by $V_2S_1W_1$ in T_2 (91.60, 90.70 and 89.91%) and $V_3S_1W_1$ in T_3 (90.69, 89.86 and 89.52%) respectively for all of the oblong seeds (Fig. 3). The average spacing between two consecutive long-oblong seed varied from 18.00 to 23.41 cm against the recommended 15-20 cm spacing. Data shows that the spacing between two seeds and their resultant uniformity percent varied and slightly decreased with increased speed and wheel sizes. The coefficient of uniformity percent was highest as treatment combination $V_1S_1W_1$ in T_1 (91.43, 92.87 and 90.14%) followed by combination $V_2S_1W_1$ in T_2 (90.32, 89.56 and 89.26%) and $V_3S_1W_1$ in T_3 (89.78, 89.34 and 88.96%) respectively for all of the long-oblong seeds. All the uniformity values for round, oblong and long-oblong shapes were closer to recommend value suggested by crop specialists. The above results were obtained due to region of relative variation in size of oval (oblong) potato seeds and less variation in the size of round potato seeds. Hence, it could be determined that the planter achieved satisfactorily metering all shapes of the potato seed and placed it in the furrow.

Number of Seed Distribution

The length of strip for 20 revolutions of different drive wheel was calculated as 23.87 m, 26.38 m and 32.67 m. An average number of seed discharges was observed which is highest in drive wheel size W_1 (38 cm) followed by W_2 (42 cm) and W_3 (52 cm), representing their number of average tuber discharge were 179.25 ± 2.50, 164.75 ± 5.50 and 153.75 ± 4.78 for the round tubers. Average discharge number of oblong seed was observed highest with the drive wheel W_1 followed by W_2 and W_3 their representing average values were 144.75 ± 3.40, 141.25 ± 2.50 and 137.32 ± 5.29 for the oblong tubers and average discharge number of long-oblong seed was observed highest with the drive wheel W_1 followed by W_2 and W_3 their average values were 140.25 ± 2.21, 136.50 ± 2.64 and 132.54 ± 1.63. It was noticed that there was a significant role of operation speed on the seed distribution pattern, as lower the machine speed as higher the seed on the strip whereas higher the speed of the planter as lower the number of distributed seed in the row.

Seed germination

The average germination percentage of potato seed was recorded as round (86.4 ± 1.14%), oblong (81.6 ± 1.14%) and long-oblong (79.6 ± 1.14%) for unmetered planted seeds with a CV of 1.31, 1.39 and 1.43% respectively. For the metered seeds, germination percentage was found as round (81.3 ± 2.38%), oblong (79.4 ± 1.14%) and (78.4 ± 1.14%) respectively. The difference in germination percentage between unmetered and metered was found less than five% which revealed that seed metering unit of the planter functioned satisfactory and the results were within permissible limits.

Theoretical field capacity, effective field capacity and field efficiency

The average machine forward speed was estimated to be 2.0 km/h stated earlier which is within the designed speed range of 1.5 to 2.3 km/h. Time observed to cover the strip was in range of 84 to 127 seconds as length of strip was 56 meters along the row, the various range of speed to cover this length of strip at the mentioned time was 2.4 to 1.5 km/h or vice versa. The overall average time to cover the strip of field was 102.20 ± 18.59 sec. and the speed was 2.02 ± 0.35 km/h, respectively. Maximum theoretical field capacity was found as 0.150 ha/h at the speed 2.5 km/h followed by 0.120 ha/h at the speed of 2.0 km/h and 0.090 ha/h at the speed of 1.5 km/h, respectively. Effective field capacity was increased as the speed increased. Maximum effective field capacity was observed as 0.106 ± 0.005 ha/h at the speed 2.5 km/h followed by 0.089 ± 0.007 ha/h at the speed of 2.0 km/h and 0.065 ± 0.001 ha/h at the speed of 1.5 km/h respectively. Maximum average field efficiency was 74.193 ± 6.018% at the speed of 2.0 km/h followed by 72.069 ± 1.351% at speed of 1.5 km/h and 70.704 ± 3.217% at speed of 2.5 km/h respectively (Table 1).

The average field efficiency recorded at the various speeds are presented in Table 1. The ranges varied from 67.54 to 73.97% at the speed of 2.5km/h, 67.24 to 77.67% at the speed of 2.0km/h and 70.61 to 73.27% at the speed of 1.5 km/h respectively. As per the researcher's development the field efficiency between 60 to 70% are optimum for satisfactory performance of the planter operation and this was a good indication. The pulling force varied at different occupied speeds from minimum 82.7 kgf to a maximum 95.5 kgf at 35.5° angle of inclination at the redecided speed range. The ranges of pulling force at the speed of 1.5, 2.0 and 2.5 km/h was 82.7 to 85.2 kgf; 85.8 to 88.1 kgf and 93.9 to 95.5 kgf, correspondingly. The draft computed varied from 67.32 kgf (660.2 N) to 77.74 kgf (757.6 N). The average draft recorded at the speed of 1.5 km/h, 2.0 km/h and 2.5 km/h were 68.41 ± 1.02, 70.93 ± 0.97 and 77.15 ± 0.65 kgf (Table 2 and Table 3), respectively. The overall average power required for potato planter was recorded as 0.53 ± 0.14 hp operated by a pair of bullocks with an an average output of 0.50 hp. Power required at the speeds of 2.5 km/h, 2.0 km/h and 1.5 km/h was 0.67, 0.54 and 0.39 hp, respectively.

Placement depth of seed, row spacing, height and width of ridge

The average placement depth of potatoes was found maximum for S_1 (20.36 ± 0.62 cm) followed by S_2 (19.98 ± 1.08 cm) and S_3 (15.06 ± 1.35 cm). The penetration depth obtained for all types of furrow opener was within the desirable limit as 15-20 cm. In case of S_1 the depth range between 19.60 to 21.30 cm and the mean was 20.36 ± 0.62 cm, for S_2 it was 15.50 to 18.10 cm and the mean was 16.98 ± 1.08 cm for S_3 type it was 13.20 to 16.80 cm and the mean was 15.06 ± 1.35 cm which was under depth recommendations for potato tubers. The average distance between rows was 60 cm and does not vary between all consecutive ridges, indicating the ridges are uniform. Row spacing, height and width of ridge was independent to different speeds. The height hierarchy of ridges was varied from 18.80 to 22.80 cm and average height was 20.83 cm which were in recommended levels.

Slip percentage and quality of feed index

Maximum wheel slippage 5.72% at the speed 2.5 km/h followed by 4.36 % at speed of 2.0 km/h and 3.17 % at speed of 1.5 km/h were recorded. It was inferred that when speed increased, the time to contact traction wheel to the soil mass of the field reduced which increased the wheel slippage due to less soil

Table 1: Average values of theoretical field capacity, effective field capacity and field efficiency

Properties	*Speed, km/h*	*Mean ($\bar{x}$)*	*Sd (σ)*	*CV%*
Theoretical field capacity, ha/h	1.50	0.09	0.00	0.00
	2.00	0.12	0.00	0.00
	2.50	0.15	0.00	0.00
Effective field capacity, ha/h	1.50	0.07	0.00	1.88
	2.00	0.09	0.01	8.11
	2.50	0.11	0.01	4.55
Field efficiency %	1.50	72.07	1.35	1.88
	2.00	74.19	6.02	8.11
	2.50	70.70	3.22	4.55

Table 2: Draft recorded at different speed

Speed, km/h	*Avg. pull, kgf*	*Angle of inclination, Radians*	*Avg. draft kgf ($\bar{x}$)*	*Sd (σ)*
1.5	84.03	35.5	68.41	1.02
2.0	87.13	35.5	70.93	0.97
2.5	94.77	35.5	77.15	0.65

Table 3: Average power calculated at different speeds

Draft, kgf	*Speed of operation, km/h*	*kW/h*	*hp*
68.41	1.50	0.29	0.39
70.93	2.00	0.40	0.53
77.15	2.50	0.50	0.67
Mean ($\bar{x}$)	1.93	0.39	0.53
Sd (σ)	0.40	0.10	0.14

resistance on the traction wheel. The quality of feed index was calculated based on multiple indices and missing indices. The maximum quality of feed index as 93.48% was found at 1.5 km/h followed by 93.01% at 2.5 km/h and 92.14% at 2.0 km/h speed.

Conclusions

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 the selected machine design and fabrication criteria, 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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