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Evaluation of Field Performance and Operating Cost of Developed Potato Planter Operated with Power Tiller

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A B S T R A C T

A Power tiller operated cup type potato planter was developed and field performances along with operating cost were also evaluated. Potato planter maintains a single row of spacing 620mm and seed to seed distance 250mm. This planter singularizes the seed by a series of cups equally spaced that pass vertically through the seed box for taking one piece of seed per cup. The planter performs for mechanical functions simultaneously, *viz.,* opening furrow, metering the seed, making ridge along with covering the seed. Four operating speeds and five seed sizes were varied to evaluate the planter. It was found that forward speed of 2.6 km/hr is the best in respect of uniformity of spacing between tubers. Field demonstrations were conducted at college farm. The average effective field capacity of planter was 0.12ha/hr with an average fuel consumption of 1.25 lit/hr. Potato planting cost and labour requirement by cup type planter and conventional method were Rs 2270/ha, and Rs5600/ha, and 4, and 45 man-days/hr, respectively. The planter saved 61% cost and 91% labour requirement compare to conventional method. Break-even point of the potato planter was 7.6 ha. The internal rate of return of the investment of the cup type potato planter was optimum at 8% df, which implies that one rupees investment in potato planter would give returns on an average Rs. 4.25 annually from the date of investment until the end of planter's life. The benefit cost ratios of the investments on potato planter were found to be more than 1 which indicated that the potato planter was profitable.

Introduction

Agricultural machinery plays an important role to reduce drudgery of farm work as well as to sustain crop production at economic level. In the recent years, the number of power tillers is increasing day by day due to its versatile use in tilling, pumping, threshing, husking and transporting. Studies indicate that there is no alternate way to minimize labour shortage at peak crop season without using farm machinery. Since 1990, Farmers became more concerned with mechanical cultivation and the rates of machinery use are increasing, Animal power is slowly decreasing because

of high rearing cost and lack of feed and this caused import of Chinese power tillers to fill-in the gap of draft power shortage, At present more than 80% agricultural activities are carried out with power tillers (Rashid, 2007).

Potato planter improves quality of work and ensures precision placement and efficient use of costly inputs like seed, fertilizer, etc,. Potato is a highly nutritious food that provides many essential vitamins, minerals and is an important supplemental source of nutrients and calories for people living on rice-

dominated diets. Potato excels the cereals not only in production and calories but also in quality of protein and takes much shorter time to grow, thus potato can really be the alternate tool in solving the food problem and alternate to rice particularly in developing countries like India, Agricultural operations are highly time bound and farmers prefer to do their jobs on time. Timely planting is a pre- requiremnt for good crop harvest. Potato planting operation is carried out manullay by labourers which is time consuming. Short supply of labour creates probles of timely planting. Due to delay planting, farmers could not get better yield as compared to their high investment. Maximum yield and low disease incidence were recorded in crop planter before 15 October. With delay in planting, disease incidence increased significantly resulting in maximum yield loss (47.9%) for crop planted on 1st december (Singh *et al.,* 2005). Farmers are facing problem with high cultivation cost. Potato planter can help farmers to minimize the prodution cost considerably. Therefore, farmers feel justification for such a type of machine which can reduce the production cost and increase the profit. Therefore there was requirement to develop such type of planter with objectives:1) to develop a cup type potato planter attachment wuth poer tiller; 2) to evaluate performance of developed planter under different soil conditions and 3) to compare the cultivation cost with convention method.

Materials and Methods

The experiment was conducted in the Department of Agricultural Engineering, Bihar Agricultural University, Sabour, Bhagalpur, Bihar, India. The locally available variety of potato was used for this purpose. These varieties were selected because they are used by many farmers in the state and have high yielding. Two experiments were organized separately. The experiment was

conducted for potato to evaluate the seed/tuber delivery of developed planters. The materials used for fabrication of planter are drills machine, Lathe machine, Grinding machine, Cutting blade, Round file, Gas welding machine, Electric welding machine, tapes, Scale, Vernier callipers, Centre punch, Hammer, Chisel, Scissors, Vice, Spanner, Screw driver, Hand grinder and Flat file.

Design of cup type potato planter

Seed hopper

The seeds container as the name implies is a device in which the seeds to be planted are kept before their gradual release into the furrowed tunnel. There was a semi conical shaped hopper fabricated for the purpose.

To ensure free flow of seeds, the slope of the hopper was fixed at 30^0 , which is modestly higher than the average angle of repose of the seeds. The material used for the design was 2mm thick mild steel sheet metal. The size of the hopper was designed by following formula (Khan *et al.,* 2015)

Volume of seed hopper $V_b = 1.1 \times V_s$ (1)

Where V_s is the volume of seed,

$$V_s = \frac{\text{Weight of seed in the box}\,(Ws)_s g}{\text{Bulk density of the seed}\,(\gamma_s)_s g/cm^s} \cdots \cdots (2)$$

Seed metering device

For the design of seed metering device the most important thing is that how many cups would be developed for desired crop; so that the spacing between the plants can be maintained. The number of cell on the seed metering device is calculated by formula (Khan *et al.,* 2015)

$$Ns = \frac{\pi \times ds}{N \times s} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

Where,

D_w= diameter of drive wheel, m
N= drive ratio and
S= plant spacing, m

Now the second thing is that what would be the diameter of the seed metering device. So the diameter of the seed metering device is:

$$D_m(cm)\frac{V_r}{\pi \times N_r} \quad\quad\quad \dots\dots\dots\dots\dots\dots\dots\dots(4)$$

Where Vr is Peripheral velocity of seed metering device in m/min and Nr is rpm of seed metering device.

Consider a specific forward speed of power tiller without any wheel slippage. Following equations are used to design the proposed potato planter (Fig. 1):

The number of potato seeds in a certain row may be calculated from equation (5)

$$N = \frac{\pi D_1 n_2}{d} \quad\quad\quad \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots(5)$$

In the same time, linear distance moved by the metering disk for same number of potato seeds delivery is (N×d)

Since, N×d = $\pi D2n1$

Hence, N=$\frac{\pi D_1 n_2}{d}$ (6)

From equation number (5) and (6)

$$N = \frac{\pi D_1 n_1}{s} = \frac{\pi D_2 n_2}{d} \text{ or,} \frac{D_1}{D_2} = \frac{n_2}{n_1} \times \frac{s}{d} \text{ (7)}$$

The relationship between rotational speed and number of sprocket teeth may be obtained for power transmission mechanism through chain and sprocket from tiller wheel.

$$\frac{n_1}{n_2} = \frac{T_2}{T_1} \quad \text{or,} \frac{n_2}{n_1} = \frac{T_1}{T_2} = k \quad\quad \dots\dots\dots\dots(8)$$

Where, k is the sprocket teeth ratio between the drive wheel sprocket and metering pulley sprocket.

Again from equation number (7) and equation (8)

$$\frac{D_1}{D_2} = k \times \frac{s}{d}$$

Thus, the equation of required potato seed metering diameter

$$D_2 = \frac{D_1}{S} \times \frac{d}{k} \quad\quad\quad \dots\dots\dots\dots(9)$$

Thus for known value of D_1, S, k approximate of matching value for D_2 and d could be selected.

Where,

D_1= Diameter of tiller drive wheel

D_2=Diameter of the metering disk

T_1=Number of teeth on drive wheel sprocket attached to the tiller

T_2= Number of teeth on metering shaft sprocket attchaed to the metering pulley

N= Total number of potato seed pieces planted per unit distance per unit time

n_1= Number of revolution per minuts of the power tiller drive wheel, rpm

n_2= Number of revolution per minuts of the metering pulley, rpm

s= required potato seed spacing in a certain row

d= potato sup spacing on metring disk

The main functional components of planter

are (i) toolbar frame (ii) hitch plate (iii) potato metering derive (iv) furrow opener (vi) furrow as well as seed covering device and (vii) power transmission of the metering mechanism.

Performance test of potato planter

Performance of the potato planter was tested both on station and in the farmer's field with a view to observe the accuracy of planting. For evaluation the performance of the potato planter following data were recorded and analysed. (i) Speed of operation (ii) Uniformity index Seed spacing (iii) Theoretical field capacity Number of seed missing (iv) Effective field capacity (v) Field efficiceny (vi) Labour requirement (vii) operating cost

$$S = \frac{3.6 \times d}{t} \ (10)$$

Where S is Travel speed (km/hr), d is Pre-measured distance, m and t is Recorded time (sec)

Seed size and forward speed

Five different whole tuber seed sizes (25, 30, 35, 40 and 45 mm) with four different forward speeds (1.5, 2.6, 3.2 and 4.2 km/hr) of power tiller were considered for the experiment of cup type potato planter. For calculating forward speed, two standing sticks fixed pre-measured distance. At the time of sowing, fixed distance passing time was recorded by stopwatch and simple calculation was done.

Uniformity of spacing and uniformity index

Uniformity of spacing is the index of planting any seeding operation. The parameters commonly used to express this uniformity are the coefficient of variance (CV) of the

spacing between successive seed pieces. The standard procedure of the International Organization for Standardization, ISO (1982) was maintained. The sample mean and sample variance of the seed spacing were taken and calculated. Generally it is expressed as percentage. The following are the equation of uniformity calculation (Hossain *et al.,* 2015):

$$CV = \frac{\sqrt{V_x}}{x} \times 100 \qquad\qquad \dots\dots\dots\dots\dots\dots\dots\ (11)$$

Where, CV = coefficient of variation, %; x= mean value of sample, mm; v_x= variance of sample seed spacing, mm

$$\text{Uniformity index} = \left(1 - \frac{\sqrt{V_x}}{x}\right) \times 100 \qquad \dots\dots\dots\dots\dots\dots\dots\ (12)$$

Theoretical field capacity

Theoretical field capacity was calculated as follows (Meri *et al.,* 2002).

$$TFC = \frac{W \times S}{10} \ (13)$$

Where TFC is Theoretical field capacity (ha/hr), W = Width of the seeder (m) and S is Travel speed (km/hr)

Effective field capacity

The effective field capacity of the potato planter is a function of the rated width of the planter, the percentage of the rated width actually utilized, the speed of travel, and the amount of field time lost during the operation. It is the actual average rate of coverage by the planter. Effective field capacity is usually expressed as hectare per hour. It is calculated by following formula (Kepner *et al.,* 1978):

$$EFC = \frac{A}{T} \ (14)$$

Where, EFC= effective field capacity (ha/hr), A= actual filed coverage (ha) and T= Total time of planting (hr)

Field efficiency

It is the percentage of the ratio of effective field capacity and theoretical field capacity (Kepner *et al.,* 1978).

$$F_e = \frac{EFC}{TFC} \ (15)$$

Where,

Fe = Field efficiency (%)

Cost calculation

Cost calculation was done on the basis of fixed cost and variable cost of the potato planter. The related cost parameters were as follows: (i) Purchase price of potato planter (ii) Depreciation (iii) Salvage value of the planter (iv) Planter life year (v) Bank interest, % (vi) operating cost, Rs/day (vi) Fuel consumption, lit/h (vii) Lubrication cost (viii) Repair and maintenance cost and (ix) Power Tiller hire price for planter operation.

Cost of conventional planting method was also recorded for cost comparison with mechanical planting. Thus, the total cost of planting was the sum of fixed cost and variable cost of the planter (Hunt, 1995).

Cost benefit analysis

Cost benefit analysis was taken into consideration for evaluation of the power tiller operated potato planter utilization in the farmer's field. The discount measures commonly used in agricultural projects: Benefit cost ratio (BCR), net present value (NPV), and internal rate of return (IRR) were used to measure the economic viability of the average earning power of an investment over the total life. In other word, IRR is the discount rate that makes NPV equal to zero. This shows maximum possible return on investment of the potato planter. The BCR,

NPV and IRR are calculated as per following formula (Hossain *et al.,* 2015):

$$BCR = \frac{\sum_{t=1}^{n} \frac{B_t}{(1+i)^t}}{\sum_{t=1}^{n} \frac{C_t}{(1+i)^t}} \ (16)$$

$$NPV = \sum_{t=1}^{n} \frac{B_t - C_t}{(1+i)^t} \ (17)$$

IRR= Lower discount rate+ difference between discount rates

$$X = \frac{NPV \ at \ lower \ discount \ rate}{Sum \ of \ two \ NPV \ ignoring \ sign}$$

IRR is that discounted rate 'I' such that

$$\sum_{t=1}^{n} \frac{B_t - C_t}{(1+I)^t} = 0 \qquad (18)$$

Where, B_t = benefit in year t; C_t = cost in year t; t= 1,2,3……….n and n=number of years i= interest (discount) rate, %

Break even use

The break even use (BEU) can be determined by the following equation:

$$BEU = \frac{AC}{CR - VC} \qquad \text{…… …… …… …… …… ….} \ (19)$$

Where,

BEU= Break even use (ha/yr)
AC=Annual ownership costs (Rs/Yr)
CR=Custom hire rate (Rs/ha)

Results and Discussion

Development of potato planter

All the parts of the planter were fabricated from mild steel material, the seed funnel which was made from rubber material, and the tuber tube which was also made from rubber material. The choice of material for the

seed funnel and seed tube was used because the coefficient of restitution for plastic material is lower than that of a mild steel sheet of the same thickness. The opted material will go a long way in minimizing seed bouncing, thereby protecting the seeds from damage due to impact. The hopper was fabricated using 2mm thick mild steel metal sheet having capacity of 10 kg. The metering mechanism was fabricated from good quality wood and metal sheet. It was observed that the number of teeth in small gear sprocket and large gear sprocket was 15 and 37 respectively.

The main frame which supports every other component of the planter was fabricated using mild steel flat bar of length of 750 mm and width of 450 mm. The adjustable furrow opener and furrow closer were both fabricated using M S flat bar and MS metal sheet respectively.

Lever type gear arrangement was provided for easy lifting of furrow closer discs when not in operation of while travelling on road (Fig. 1). The planter's transport wheels were fabricated using a 25mm MS metal sheet and 17 lugs were welded on periphery of transport wheel to provide additional friction during operation.

Fabrication with appropriate dimension of the potato planter components were carried out according to the designed equation (5) (Table 1). Potato planter was shown in figure 1. There were 13 pairs of potato cups fixed on a 40 mm flat belt, forming an endless loop. The cup size is 40 mm. According to the design criteria, potato cups were positioned 110 mm apart from each successive cup to provide he recommended 250 mm spacing for planting whole potato seeds. The belt was coupled between drive and driven pulleys 780 mm distance vertically arranged on the toolbar frame. The diameter of the seed metering

device pulley was 120 mm. the sprocket ratio was 2.2 for obtaining desired seed spacing 250 mm. In the forward speed of potato planter without drive wheel slippage metering cup hold one piece seed and release it near the bottom of the open furrow.

The spacing between one seed to another seed was controlled by the metering pulley rotation through sprocket ratio and power transmission arrangement. For satisfactory planting operation, 3.5 kg graded potato seed needs to be deposited in the secondary seed box. The planter regulates seeds automatically. Main operator can perform planting operation alone.

Effect of forward speed and seed size on uniformity index

Uniformity of spacing was evaluated for potato planter with different seed sizes (25, 30, 35, 40 and 45 mm). Uniformity of spacing varied with the increase of operational speed (Fig. 3). Uniformity index of seed distribution decreased with the increased of forward speed of potato planter. Among the five seed sizes, it was observed that the 35mm size showed higher uniformity index than that of 25, 30, 35, 40 and 45 mm size. The seed size 45 mm produced the lowest uniformity index.

There were significant variations of uniformity index among the seed sizes. At higher speed, cup could not pick seed pieces properly. The cause of this variation was due to missing seeds into the cups during the planting operations. Different seed sizes exerted different loads on the metering cups of belt during the belt movement through the secondary seed box. So, operational seed should be selected carefully for more planting accuracy. Similar results were obtained by Khan *et al.,* (2015) for single row multi-crop planter and Hossain *et al.,* (2009) for potato planter.
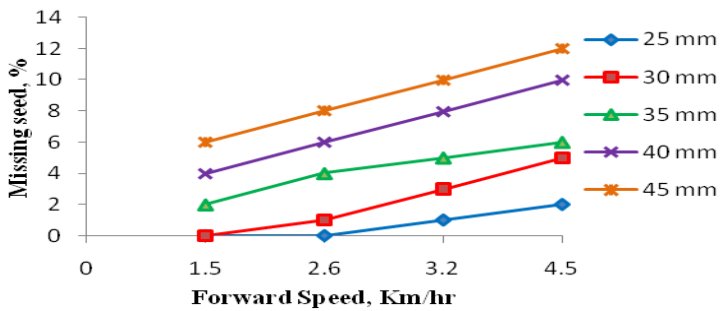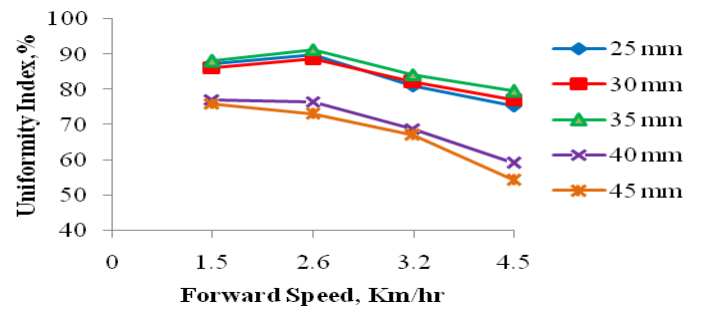
Fig.1 Planter attached with power tiller

Fig.2 Covering of seeds with bund former

Fig.3 Effect of forward speed on missing seed by planter

Fig.4 Uniformity index of seed placement on forward speed and seed size by planter

Table.1 Specification of developed potato planter

Particulars	No. of Items	Dimension (mm)	Fabricated Material
Frame	1	750×450	M.S.Flat bar
Hopper	2	H_p:430×330×70 H_m:290×160×90	M.S.Sheet metal
Seed metering	2	Cup type	Medium carbon steel and carbon
Transport wheel	2	Dia-350 each	M.S. Sheet metal
Lugs	17	50×40 each	M.S. Sheet metal
Distance between transport wheels	1	Dia -570	M.S. Sheet metal
Teeth in small gear sprocket	15	Dia -60	M.S. Sheet metal
Teeth large gear sprocket	37	Dia -180	M.S. Sheet metal
Bund former disc	02	Dia -350 each	M.S. Sheet metal
Shaft	2	Dia -30 each	Medium carbon steel
Cups	24	Dia -60 each	Metal wire
Spacing between cups	-	80	Metal wire
Seed tube	1	Length-650, Dia-30	Plastic
Blocks	8	Dia -60 each	Bronze
Pintel chain	1	No of links-100	Malleable links
Furrow opener	1	L=100, W=90	M.S. Flat bar
No. o pulley	03	Dia_1-160, Dia_2-80, Dia_3-80	M.S. Sheet

Table.2 Field performance of the potato planter

Parameters of potato planter	Observed data
Average forward speed, km/hr	2.6
Width of planter, mm	620
Theoretical field capacity, ha/hr	0.14
Effective field capacity, ha/hr	0.12
Field efficiency, %	81.6
Average fuel consumption, lit/hr	1.25

Effect of seed size and forward speed on missing seed

The missing seed percentage varied depending on seed sizes and different forward speeds of operation. In cup type potato planter, missing seed percentage were found more with the larger potato seeds compare to smaller seed size (Fig. 4). The missing seed percentages were found to be increased with the increasing rate for the increase of forward speed for any seed size. The increasing rate was lower in first three speeds for all the seed sizes but it drastically increased with the higher operational speed. At slower speeds, potato seeds had more time to be held properly in the cup space one after another in the vertically moving cup. At the faster operating speeds, potato seeds had less time for being caused by the cups. Thus, there was more possibility to have missing seed or skips. This result is in line with results of Khan *et al.,* (2015) for single row multi-crop planter and Hossain *et al.,* (2009) for potato planter.

Field performance of the potato planter

Potato planter adaptive trial was conducted at different locations of BAC farm of Bihar Agricultural University, Sabour in the district of Bhagalpur state of Bihar, India. In these trials, the potato planter field performances were evaluated on the basis of uniformity of spacing, planting cost and benefit, Potato planter, planting view in the farmers filed. In these trials average seed size of 35 mm used for cup type planter with operating speed of 2.6 km/hr. Cup type planter can form bed of 620 mm size per pass. Field performance of power tiller operated

potato planter were calculated on the basis of areas coverage, opening speed, effective time coverage, width of planting and fuel consumption. From table 2 it was found that the effective filed capacity and filed efficiency of developed planter was 0.12 ha/hr and 81.6% respectively. Also it was observed that average fuel consumption of the potato planter was 1.25 lit/hr. It was also found that EFC varied on field size and shape. EFC was more in large filed size compare to small field size and irregular shape of field. EFC and field efficiency can be increased through operator intensive training on machinery management which improves skills. These results were in agreement with those reported in some previous studies (Aikins *et al.,* 2010). It was found that cos of operation was Rs. 2270/ha. On the other hand using whole tuber and cut piece seed, manually potato planting cost was Rs. 5200/ha and Rs.6500/ha. Labour requirement for whole tuber seed planting in case of planter and conventional method were 4 man days and 45 man days, respectively. Potato planter can save labour requirement of 36 man days/ha and planting cost Rs 2930/ha which was equivalent to 91% and 61 % saving of labour and cost, respectively compare to conventional potato planting method.

Break-even used (BEU) of power tiller operated potato planter was calculated on the basis yearly land use and custom hire rate of potato planter. It was observed that cost of potato planting per hectare decreases with the increase of yearly land area use. Presently custom hiring rate of the potato planter in the field is Rs 4500/ha. Break-even use of the planter was calculated as

7.8 ha. This BEU indicated that machine owner must plant 7.8 ha land for his yearly no loss margin. A potato planter owner or an operator should make a target maximum area for a year to pay back the investment.

The NPVs of the investment were estimated for the planter for 10 years life. On the other hand using the base parameters, the IRR of the investment on the cup type potato was estimated to be minimum, which implies that one rupee invested in potato planter gives return on an average Rs 4.25 annually from the date of investment until the end planter life. It was also found that BCRs of the investments were found to be more than 1 which indicated that the potato planter was profitable. This result is in line with results of Khan *et al.,* (2015) for single row multi-crop planter and Hossain *et al.,* (2009) for potato planter.

This work focused on development, performance and operating cost of planter operated with power tiller. The developed planter is cheap, easily affordable, easy to maintain and less laborious to use. The depth of seed in the secondary chamber should be maintained at constant level so that all cups receive seed piece effectively. The picking chamber should be approximately two thirds full for better performance. The planter performs satisfactorily at the operating speed of 2.6-3.2 km/h with seed size 30-35 mm. Labour requirement for plantation by using a potato planter and conventional method was 4 man day/ha and 45 man days/ha respectively. BCR of the investment of potato planter was found to be more than 1 which indicated that the potato planter is profitable. The planter will go a long way in making farming more attractive and increasing productivity. This machine will be widely accepted by the small and marginal Indian farmers.

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