Australian Journal of Engineering and Innovative Technology, 6(1), 19-25, 2024

Publisher homepage: www.universepg.com, ISSN: 2663-7804 (Online) & 2663-7790 (Print)

https://doi.org/10.34104/ajeit.024.019025

Australian Journal of Engineering and Innovative Technology

Journal homepage: www.universepg.com/journal/ajeit

Field Performance Evaluation of a Power Tiller Operated Potato Planter

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ABSTRACT

The research aimed to evaluate the field performance of a potato planter powered by a power tiller at the Regional Wheat Research Institute, BARI, Rajshahi. The study was conducted at a farmer's field in the potato-growing region of Shyampur, Rajshahi, from August 2013 to January 2014. The planter maintained a 250 mm gap between seeds and a single row spacing of 60 mm. Field trials were conducted at different operating speeds and seed sizes for assessment. The study revealed that an optimal forward speed of 2.5 km/hr resulted in the most uniform seed spacing and minimal seed gaps. Field demonstrations in Shyampur showed the potato planters' average effective field capacity was 0.11 ha/hr, with a 5% seed absence rate. In comparison to the traditional manual planting method, which required 53.3 man-days/ha, the potato planter significantly reduced labor requirements to 3 man-days per hectare. The total cost of planting was Tk.1781.82/ha. While the conventional method slightly outperformed mechanically planted plots in yields, using the power-tiller-operated potato planter demonstrated significant savings. A farmer's field day showcased crops from both planting methods, highlighting the substantial labor (95%) and cost (53%) savings achieved by adopting the mechanical planting approach. Considering the comparative performance, it is recommended that low-income farmers adopt the power tiller-operated potato planter to increase planting efficiency, cover more area in less time, and significantly reduce production costs compared to traditional methods.

Keywords: Potato, Potato planter, Field implementation, Performance evaluation, and Cost comparison.

INTRODUCTION:

Potato planting constitutes a crucial pre-harvest operation in potato production, accounting approximately half of the labor requirements. Conventional methods are costly, labor-intensive, and time-consuming, resulting in a gradual increase in yields from ten to eleven tons per hectare. In Bangladesh, the primary driver for future production advancements is the pursuit of increasing the yields. With an average per capita consumption of 37 kilograms and an estimated overall production of 52,000,000 tons in 2006, potatoes offer significant potential for increased area (BBS, 2006).

Technological advancements and the cold storage facilities have led to enhanced potato yields, and the preference among Bangladeshi farmers to cultivate potatoes during the colder months has grown.

Mechanization has streamlined timely operations, with potato planters increasing labor standards, ensuring precise placement, and optimizing the cost-effective use of inputs like seeds and fertilizer. The adoption of potato planters aims to reduce labor requirements, especially during the peak potato planting season. According to Singh and Gulati, (2003) most potato planters has the ability for fertilizer placement in fur-rows, either in single or double bands, positioned 3 to 5 cm below the seed and 5 to6 cm far on both sides of the row. A 4-row tractor-drawn fertilizer drill cum marker can cover up to 1.5 hectares per day and requ-ires a tractor with 20-35 horsepower to run. During period of high labor demand, the timely completion of tasks by a potato planter generally results in higher revenues and makes it easier to complete other tasks quickly for the best rewards. Migration of agricultural laborers during the planting season often affects labor-intensive jobs, such as plan-ting operations. Manual potato planting is a time-consuming process that can lead to financial losses and a decline in the nation's GDP. Singh *et al.* (2005) found that maximum yields and low disease incidence were recorded in crop planted before October 15. Planting practices vary depending on soil type, labor availability, and crop-ping patterns. Potatoes are manually planted with row spacing ranging from 45 to 60 cm, and mulching is used for soil moisture retention and weed manage-ment. Harvesting is also done manually using basic equipment. Therefore, in Bangladesh, the introduction of an appropriate mechanical potato planter is crucial to address delays in potato planting, reduce costs, and promote the overall mechanization advancement in potato cultivation.

Objectives of the study

This study aimed to compare the field performance of a power tiller-driven potato planter with manual potato planting. The specific objectives of the study were:

- To assess and evaluate the performance of a potato planter driven by a power tiller on the farmer's field.
- To analyze and compare the costs associated with conventional manual potato planting and potato planter planting.

MATERIALS AND METHODS:

The field implementation and evaluation of the potato planter took place in a farmer's field situated in the potato-growing region of Shyampur, Rajshahi, Bang-ladesh. These field trials were conducted over the period from August 2013 to January 2014.

Methods of potato plantation

The potato planter functions similarly to a tiller, plan-ting potato seeds at regular intervals while simul-taneously tilling the soil. Potato planting in Bangla-desh involves two methods- planting whole tuber potato seeds and planting chopped piece seeds. The typical procedure for sowing entire tuber seeds, in-cluding sowing 'A' grade seed (28-40 mm) properly, requires maintaining a seed-to-seed distance of 20-25 cm and keeping a gap of 60 cm between lines. For sowing cut seeds, the typical procedure involves an average seed size of 20g and a spacing of 60 x 16 cm. The cups take the seed out of the hopper, pass it over an opening in the furrow, and then drop it into the furrow at the necessary distance. This study evaluates both methods of potato seed plantation. The primary driving force for the potato planter is a power tiller.

Construction of potato planter

The potato planter was constructed using locally available materials such as MS Sheet, angle bar, steel shaft, etc. Its primary components include (i) a hopper for potatoes; (ii) a gang of rotating blades; (iii) a cup-style metering mechanism; and (iv) a roller-style bed maker. The design of this planter aligns with the recom-mended agronomic practice of potato planting by the Tuber Crops Research Centre (TCRC) of the Bangla-desh Agricultural Research Institute (BARI). A power tiller-operated potato planer was also developed in the FPME division of BARI, consisting a frame, furrow opener, seed metering unit, ridger, and V-shaped soil compactor (Wohab *et al.*, 2004). The design parame-ters and operation mode of power tiller-operated potato planter are illustrated in **Fig. 1**, where D1 is the tiller driving wheel's diameter, D2 is the metering disk's diameter, T1 is the number of teeth on the tiller-attached drive wheel sprocket, T2 is the metering shaft sprocket's tooth count connected to the metering pulley, N is the total number of potato seed pieces sown in a given time and distance, n1 is the power tiller drive wheel's revolutions per minute (rpm), and n2 is the metering pulley's rpm.

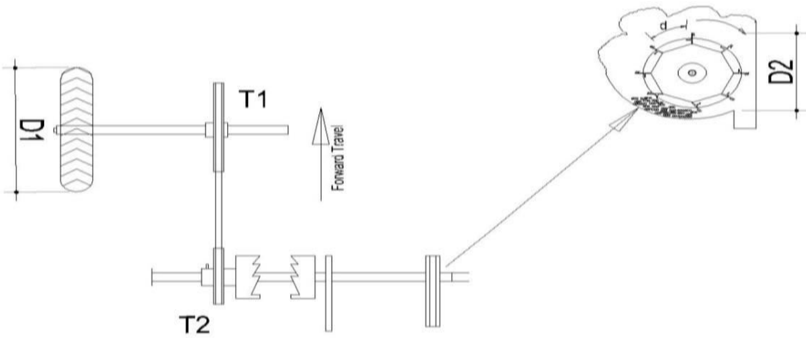

Fig. 1: Design parameter and operation mode of potato planter.

Collection of test data

Data were systematically collected following the test code of the Regional Network for Agricultural Machinery (RNAM) for each test run in this study. The recorded parameters included operational speed, distance between seeds, quantity of absent seeds, theoretical field capacity, effective field capacity, labor needs, and planting expenses.

Operational speed

The operational speed also known as forward speed, was calculated using the following equation.

$$S = \frac{d}{t} \times 3.6 \qquad \text{(1)}$$

Where, S= operational speed (km/hr); d= distance (m); t= recorded time (sec)

Distance between seeds

The drive wheel sprockets are easily interchangeable, providing a straightforward means to adjust seed spacing. The available series of sprockets allows for seed spacing distances between 10 and 30 cm. With a sprocket size of 44, it is feasible to maintain seed spacings of 20 to 26 cm for cup-type planters and 13 to 17 cm for pick-type planters. Additionally, planting depth can be customized by adjusting the toolbar to move the furrow opener deeper or higher, or by adjusting the wheel up and down.

Quantity of absent seeds

Through field testing and farm trials conducted in the farmer's fields, the study assessed the impact of seed piece size and operational speed on the performance of the potato planter. The evaluation utilized metrics such as the number of missing seeds, wounded seeds, doubles, and the regularity index of spacing created during the planting procedures to quantify the accuracy of seed placement.

Theoretical field capacity

The theoretical field capacity, a measure of the rate of field coverage that would be attained if the machine consistently operated at its rated forward speed 100% of the time and covered 100% of its rated width, was calculated according to the method described by Mari *et al.* (2002).

$$TFC = \frac{SW}{10} \qquad \text{(2)}$$

Where, TFC stands for theoretical field capacity (ha/hr), W is rated width of the planter (m), and S is rated forward speed (km/hr).

Effective field capacity

The effective field capacity is a measure of the actual average coverage rate of the planter during the total field time. It reflects the real average coverage rate, considering factors like the planter's rated width, the portion of the rated width that is actually used, the planter's movement speed, and the overall amount of field time lost throughout the operation. It is typically expressed in hectares per hour. The formula from Kepner *et al.* (1978) was used for its calculation.

$$EFC = \frac{A}{T} \qquad \text{(3)}$$

Where, A is actual field coverage (ha); T is total planting time (hour); and EFC is effective field capacity (ha/hr).

Field efficiency

Field efficiency is defined as the ratio of the effective field capacity to the theoretical field capacity, expressed as a percentage. This metric account for the impact of idle time during field operations and the underutilization of the planter's entire width. The field efficiency of the potato planter is calculated using the formula proposed by Kepner *et al.* (1978).

$$FE = \frac{EFC}{TFC} * 100 \quad \ldots\ldots (4)$$

Where, FE = Field efficiency (%)

Cost calculation

The calculation of costs considered both fixed and variable expenses associated with the potato planter. The pertinent cost parameters included: (a) the purchase cost of the potato planter; (b) the salvage value of the planter; (c) life of the planter; (d) bank interest rate; (e) t annual use of the planter in hours; (f) charge for the operator in Tk./day; (g) the amount of fuel used; (h) maintenance and repair expenses; and (i) the cost of hiring a power tiller for planter operation. To facilitate cost comparisons with traditional planting methods, conventional planting expenses were also considered. The total planting cost equated to the sum of the fixed and variable costs associated with the potato planter (Anonymous, 1991).

$$AC = FC + VC \quad \ldots\ldots (5)$$

Fixed cost (FC)

Fixed costs represent expenses incurred regardless of whether the planter is in operation. The fixed cost of the potato planter was determined using the capital consumption (CC) approach. This method involves combining the total depreciation and interest changes by utilizing a capital recovery factor (CRF), which essentially represents a series of compound interest payments made annually. The estimation of the capital consumption of farm machinery is based on this payment plus interest on the underappreciated amount (Hunt, D., 2008).

$$CC = (P - S) x CRF + (S x i) \quad \ldots\ldots (6)$$

Where, P is the potato planter's purchase price in Tk.; S is its salvage value (assumed 10% of P) in Tk.; L is the planter's life in year; and i is the bank interest rate in percentage.

Variable costs (VC)

Variable expenses for a potato planter are contingent on its usage and only incur when the planter is in operation. These variable expenses are often expressed on an hourly basis. The computation of the planter's variable costs involved the consideration of following items.

Repair and maintenance costs (R&M)

Repair and maintenance (R&M) costs for the potato planter encompass the expenses related to replacement of parts after a set period, as well as any incidental costs incurred during operation. These costs mainly involve items such as nuts and bolts for the furrow opener and furrow closure, the power transmission chain, and bearings. According to Hunt, (2008) this expense is estimated to account for 5% of the potato planter's annual operating cost per 100 hours of usage.

$$R\&M = 0.05 x P \quad \ldots\ldots (7)$$

Power tiller hiring costs (H)

The potato planter was driven by a standard power tiller commonly found in farmers' fields. The cost associated with the power tiller was considered an hourly rental expense for a typical ploughing operation. The rental price for the power tiller covered the expenses of the operator and fuel.

Labor costs (L)

Wages paid to laborers were categorized as an assistant operator expense for the planter. The assistant operator's main duties included assisting the primary operator in tasks such as replenishing the seed box, transferring seeds from a nearby area of the field, and allowing time for breaks and recuperation.

Annual costs

$$AC = FC + \left(\frac{A}{C}\right) x (H+L+R\&M) \quad \ldots\ldots (8)$$

Where, A= annual area usage, ha; L= labour wage, Tk/hr; H= power tiller hire price, Tk/hr; R&M= repair and maintenance cost, Tk/hr; AC= annual cost of running potato planter, Tk/yr; FC= fixed cost, Tk/yr.

Break even use

The point at which the cost of owning a planter is the same as the cost of hiring a custom operator is known as the break-even use (BEU). The following formula can be used to calculate the Table:

$$BEU = \frac{AC}{CR\text{-}VC} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \ (9)$$

Where, VC stands for variable cost (Tk./hr), CR for custom hire rate (Tk./ha), AC for annual ownership expenses (Tk./yr), and BEU for break-even usage (ha/yr).

RESULTS AND DISCUSSION:

Thorough field trials and on-farm demonstrations in the field were conducted to assess the performance of power tiller powered potato planters that were manufactured. These planters were subjected to rigorous testing on the farmer's field to assess their planting potential, specifically for cup-type potato planters used for both chopped piece and whole tuber seed planting. The assessment considered factors such as the uniformmity of spacing, percentage of missing seeds, seed damage, and instances of double seed dropping when evaluating the effectiveness of the potato planter. The summary of the field performance evaluation of the potato planter is presented in the **Table 1**. The planter's effective field capacity and field efficiency were determined to be 0.11 ha/hr and 73%, respecttively at the recommended operating speed of 2.5 km/h.

Table 1: The potato planter's performance on the field.

SL No.	Performance parameter	Measured value
1	Average operating speed, km/hr	2.5
2	Planter's width, mm	600
3	Theoretical field capacity, ha/hr	0.15
4	Effective field capacity, ha/hr	0.11
5	Field efficiency, %	73%
6	Average amount of fuel used, lit/hr	1.20
7	Labor requirement, man-days/ha	3
8	Conventional manual method, man-days/ha	63
9	Seed spacing, cm	20
10	Seed absents, %	5

Cup type potato planter

A cup-type potato planting device was used for the planting of whole tuber potato seeds. The device consisted thirteen pairs of potato cups connected to a 4 cm flat belt, maintaining a 25 cm spacing between each cup. Each metering cup held one seed and released it as the planter moved forward without slipping. The metering pulley rotated to control the distance between seeds. For successful planting, 3.5 kg of graded seed was placed in the secondary seed box. Fertilizer was applied during planting, and the planter automatically controlled the seed placement. The main operator managed planting operations independently.

Selection of the size of seed and operational speed for planters

Based on the trial results of potato planters with varying seed sizes and forward speeds, the selection of forward speed and seed size for cup-type potato planters was determined through the consideration of uniformity index, yield, and net benefit. Statistical analysis revealed that both seed size and operational speed significantly influenced yield and spacing uniformmity. Cup-type planters demonstrated improved yield and spacing consistency with seed sizes of 35 mm and 20 g, respectively, across all forward speeds. The maximum speed resulted in the highest number of lost seeds. In addition to the planters operational speed, factors like labor efficiency, feeding rate to the planter, hopper opening size, and potato seed type contributed to the number of missing seeds (Momin *et al.*, 2006; Hossain *et al.,* 2023). According to statistical results, speed had a substantial impact on both the planters average net benefit and output cost.

Effect of the size of seed and operational speed on absent seed

The percentage of missing seeds varied based on seed size and forward operating speed. Missing seed percentages were more common in cup-style potato planters with larger potato seeds than with lower seed sizes. It was observed that, irrespective of seed size, the missing seed percentages increased with the forward operating speed, with a more pronounced growth rate at higher speeds (**Fig. 2**). The growth rate was slower at the first three lower speeds, but escalated rapidly at the highest operating speed. Slower seed movement allowed for better retention in the cup space during vertical cup movement, reducing the likelihood of seeds being missed. Conversely, faster speeds increased the probability of absent seeds or skips, aligning with similar observations in the study by Hossain *et al.* (2009) on potato planter. When operating at slower speeds, the picker type potato planter exhibited higher missing seed percent-ages for the larger seed sizes compared to smaller sizes. Conversely, smaller seeds had a higher rate of missing seeds than larger ones when the planter operated at faster speeds. The missing seed rate for smaller seeds increased at a faster pace with the speed increment. The utilization of larger seed sizes in the picking chamber, especially in the picking position, resulted in less space consumption compared to the use of smaller seed sizes.

Operating costs of planter

The operational cost of the power tiller-operated potato planter was calculated based on test results and assumptions regarding machine life, hours of operation (per day and per year), rate of interest and the cost of machine, following standard procedure.

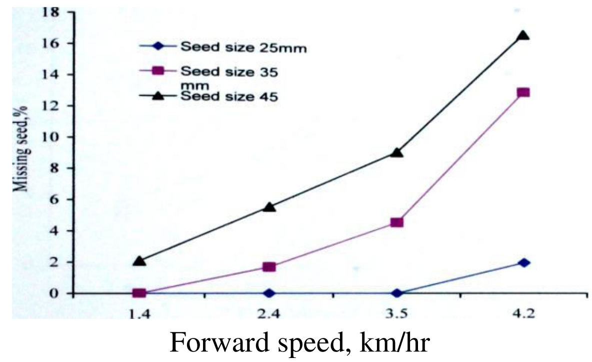

Fig. 2: Effect of operational speed on missing seed by cup type planter.

Estimated costs for the planter were determined with an effective field capacity of 0.11 ha/hr obtained at a speed of 2.5 km/hr. **Table 2** shows the estimated costs of the potato planter.

Table 2: Estimated planting cost of a potato planter driven by a power tiller.

Cost items	Potato planter
Fixed cost	
Depreciation, (Tk./yr)	2250
Interest, (Tk./yr)	1100
Taxes, insurance and shelter, (Tk./yr)	0
Subtotal fixed cost, (Tk./yr)	3350
Subtotal fixed cost, (Tk./hr)	16.75
Variable cost	
Power tiller hire price with fuel and main operator, (Tk./hr)	145
Repair & maintenance cost, (Tk./hr)	8.00
Labor cost, (Tk./hr)	26.25
Subtotal of variable cost, (Tk./hr)	179.25
Grand total of planting cost, (Tk./hr)	**196**
Grand total of planting cost, (Tk./ha)	**1781.82**

Planting cost comparison

For the purpose of comparing planting costs, conventionally planted plots were also established alongside mechanically planted plots. The cost comparison between power tiller-operated potato planter and conventional method of planting is detailed in **Table 3**. The Table indicates that at the recommended speed of operation (2.5 km/hr), the cost of planting potatoes with the planter was Tk. 1781.82 with 3 man-day/ha. In contrast, for the conventional method it was Tk. 3801 with 54 man-day/ha. Therefore, the potato planter saved about 95% in labor and 53% in planting costs compared to the conventional method of planting.

Table 3: Cost comparison between potato planter and conventional method of planting.

Potato planting methods	Labor required, (Man-day/ha)	Labor saving, (%)	Planting cost, (Tk./ha)	Cost saving (%) compared to planting whole tuber seed
Potato planter	3	95%	1781.82	53%
Manual planting	53.3	Nil	3801	Nil

Break even analysis of cup type potato planter

The break-even analysis of power tiller operated potato planter and conventional method shows the relationship between machine planting cost/ha and the total area to be cultivated. It was observed that the cost of potato planting per hectare decreases as the planted area increases. The break-even point for using the power tiller-operated cup type potato planter is 4.2 hectares. Below this threshold, potato planters may not find it economically viable to plant potatoes.

CONCLUSION:

Timely planting is crucial for achieving the optimal potato yields in pre-harvest operations. The use of a cup type power tiller-operated potato planter, both for whole tuber and cut piece seeds, significantly reduces planting time compared to the conventional methods, requiring only one operator and two workers. The potato planter demonstrates effectiveness in enhancing production quality, facilitating tilling, sequential and evenly spaced seed planting, simultaneous earthing up. Notably, it reduces planting expenses and labor requirements for potato planting by 53% and 95%, respectively, when compared to traditional methods.

ACKNOWLEDGEMENT:

The authors extend their appreciation to the Dept. of Farm Power and Machinery, Bangladesh Agricultural University, Mymensingh and the Regional Wheat Research Centre, BARI, Shyampur, Rajshahi, for the facilitating and supporting this study.

CONFLICTS OF INTEREST:

The authors declare no conflicts of interest.

REFERENCES:

1) Anonymous, (1991). Calculation method of farm machinery utilization. Farm mechanization planning, Mechanization Management, **3**, *JICA, TIA-TC, Japan*.
2) BBS, (2006). The yearbook of agricultural statistics of Bangladesh, Bureau of Statistics, Ministry of Planning, Government of the people's republic of Bangladesh.
3) Gulati, S., and Singh, M. (2003). Design and development of a manually drawn cup type potato planter, *J. of Indian Potato Association,* **30**(1-2), 61-62.
4) Hossain MA, Bhuiyan MGK, and Hossain M. (2023). Modification of the power transmission system of BRRI hydro-tiller, *Int. J. Mat. Math. Sci*., **5**(3), 19-24. https://doi.org/10.34104/ijmms.023.0190024
5) Hossain, M.D., Hossain, M.M., and Ahmmed, S. (2009). Design and development of power tiller operated cup type potato planter, *J. of Agricultural Engineering*, The Institute of Engineers, Bangladesh. Vol.37/AE, December 2009.
6) Hunt, D. (2008). Farm power and machinery management, 9th edition, *Iowa State University Press*, Ames, Iowa 50014, 4-6 and 65-75.
7) Kepner, R. A., Bainer, R., and Barger, E. L. (1978). Principles of farm machinery. 3rd Edition. West port. G, *AVI publishing company Inc*.
8) Mari, G. R., Memon, S. A., and Brohi, A. D. (2002). Evaluation of tractor operated potato planter, *J. of Applied Sciences*, **2**(9), 889-891.
9) Momin, M. A., Sarker, M. R. I., and Hossain, M. M. (2006). Field performance of a tractor operated semi-automatic potato planter, *J. of the Bang. Agricul. University,* **4**(452-2018-3927), 391-399. https://doi.org/10.22271/tpi.2022.v11.i10Sr.16347
10) Singh, B., Lakra, B. S., and Singh, M. (2005). Effect of Planting Time on Black Scurf Development in Potato, *Annals of Biology*, **21**(2), 245-248.
11) Wohab, M.A, S. Ahmed and M.N. Amin, (2004). Development of a power tiller operated potato planter cum fertilizer applicator, Annual report, October-2004. Bangladesh Agricultural Research Institute, Joydebpur, Gazipur.

Citation: Alam MF, Momin MA, Hossain MI, Akter S, khan AU, and Ahmmed MM. (2024). Field performance evaluation of a power tiller operated potato planter. *Aust. J. Eng. Innov. Technol.*, **6**(1), 19-25. https://doi.org/10.34104/ajeit.024.019025