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Feasibility analysis of the potato planters in Etawah district of Uttar Pradesh

Shishir Kumar Verma, Krishna Kumar Patel and Arun Kumar Yadav

Abstract
An investigation to field evaluate three potato planters namely four row semi-automatic potato planter with rotary magazine (P1), two row semi-automatic potato planter with endless belt and fertilizer application unit (P2) and two row semi-automatic potato planter with endless belt without fertilizer application (P3) in comparison to traditional manual potato planting using spade (P4) was conducted at farmers' field of district Etawah, U.P. situated in south-west part of India. Potato crop was grown over an area of 0.42, 1.12, 0.82 and 1.13 ha under P1, P2, P3 and P4 systems, respectively. The potato planting with planters was lesser time consuming than traditional system. The effective field capacity of the machines P1, P2 and P3 was 0.25, 0.13 and 0.12 ha/h, respectively. All the tested tractor mounted potato planters were found economical and labour saving of 87 to 90%, as compared to the traditional method of planting using spade. The planting by potato planter increased the yield by 10.5 to 19% (5.08 to 3.88 t/ha) over the spade method of planting. For accelerated adoption of potato planters there is a strong need of effective on demonstrations of these machines.

Keywords: Feasibility, potato-planter, south-west India, analysis, etc.

Introduction
Today's global population has quadrupled to 7.3 billion from 1.8 billion in 1915 and this may reach to 9.7 billion by 2050 (Elferink and Schierhorn, 2016) [4]. This growth will increase the food demand and expected to increase by between 59% to 98% by 2050, and to match the global projected population growth, global agricultural food production needs to increase by between 50% and 70% by 2050 (Sharma *et al*., 2018) [8]. Worldwide farmers, thus, will need to achieve sustainable food production. Potato is fourth most important food crop after corn, rice and wheat in terms of global production and one of the most commonly used crop (Anon, 2018) [3]. Potatoes being the staple food have potential to provide nutritive food for increasing population of the country. Peoples and communities who do not have physical or financial access to food year round noticed undernourishment. The undernourishment causes bad health that frequently ends in death. Finding the new ways to ensure food security is therefore important. One promising approach is increased potato cultivation (Hussain, 2016) [6].
About 90 per cent of the potato crop in the country is cultivated in from Indo-Gangetic planes comprising the states of Punjab, Haryana, Uttar Pradesh (U.P.), Bihar, West Bengal, Madhya Pradesh (M.P.) and Gujarat. In addition, today potato is an important cash crop in Indian agriculture. As potatoes can be processed into various forms such as chips, fries, dehydrated products (dehydrated chips, dice or cubes, *waris*, papads, flakes, granules and flour), french fries, *Aloo Bhujia*, potato flakes, potato shreds, flour and potato starch, etc. (Singh *et al*., 2016).
The record potato production in India was around 48 million tonnes received in 2014-15 and around 47 million tonnes was estimated in 2017. Uttar Pradesh is the country's top potato producing state was projected to be higher at 15 million tonnes in 2017 (TOI, 2017). The most productive region in the state is Farrukhabad, Kanauj and other high yielding neighboring districts. The average actual land holding size in Etawah district was 0.74 ha and the irrigated area was 96.5%. The average yield of potato was reported 223.3 q/ha. Etawah district is one of the largest potato growing districts but it now lacks in productivity (by 30 to 40% less yield comparatively to the neighbor districts namely, Kannauj, Farrukhabad, etc.) and quality produce because of traditional farming practices and lack of new technologies developed by different research station (Shivam *et al.*, 2017) [9]. Adaption of technology helps in timely showing of the crops which the prime importance for optimum production of the crop. For instance, the number of potato planter reported 5 to 6 per 1000ha was a cause of concern.

Since, with this machine, seeds could be in triangle shape and make reasonable use of space. All above would make a good base for increasing production and growing up. In addition, the machine could meet the various requirements of agriculture. Seed depth, ridge height, spacing and plant spacing can be adjusted. The advantage of using this machine: Labor-saving, high output, easy and comfortable operation (Anon, 2010-2012) [2]. However, about 50% of potato cropped area was planted by tractor drawn 2 to 4 row semi-automatic potato planter.

The development of a potato processing industry can provide employment Opportunities in the rural areas. Equipment for potato production and processing is needed to promote the industry. The potato plantation is directly related to the yield and the farming cost. Sometimes the farming cost increases very high because of the price of potato tubers mounting to 60% of the total potato production cost. The potato plantation is, thus, considered as a very crucial and critical operation (Ghonimy and Rostam, 2005) [5]. Thus, to minimize drudgery, to improve the crop establishment and timelines, and to reduce the costs, suitable designs of potato planters are very necessary. In order to reduce the labour, cost of cultivation, human drudgery and sustain the production, introduction and popularization of potato planter in Indian farming system is today's demand. In addition, its feasibility test by considering the socio-economic and agro-climatic conditions of the region is also necessary. Among the traditional practices of potato plantation in India seed tubers planted by manual method may be chitted (potatoes with well-developed buds or shoots) or un-chitted is very common. Size of seed potato tubers range from 25 to 40 mm in diameter and 50,000 to 60,000 tubers are planted per hectare. For planting potatoes, the labor requirement is very high. It varies from 150 to 250man/hr-ha. In addition, this planting method is very tardiness, time consuming, inefficient and non-uniform process. To avoid these back-draws, the different types of potato planters have been developed and are commercially available in the market.

Several studies have been conducted on evaluation and performance of various potato planters. Among them, Wahby *et al.* (2003) [14] evaluated potato planters in sandy loam soil and reported that in-row spacing with cup feeding planter is lower than semi-automatic and finger feed mechanism planters. In contrast, Ghonimy and Rostom (2005) [5] have reported higher coefficient of variation for tuber spacing with auto-feed cup planter than planters with either single or multi-feed belts. Similarly, Altuntas (2005) [1] and Khairy (1997) [7] have reported the effect of forward speed on tuber spacing distribution.

In Etawah district, a few tractor owner farmers have semi-automatic 2 to 4 row potato planters with and without fertilizer application device. They are using these machines for their own potato plantation. Although, some farmers are using these planters but they do not have adequate knowledge about these planters work performance, usefulness, and proper use, etc. The main objective of this work is, therefore, to study the performance of different type of semi-automatic potato planter being used in Etawah district at farmer's field and to compare the economics of potato planters in Etawah district with the conventional manual method of potato planting.

Materials and Methods

To evaluate the field performance of different potato planting machines, field trials were conducted at farmer's fields in villages; Nagla Bhadauria, Nagla Harishchand, Nagla Hulasi and Malagani in Jaswantnagar block of Etawah district of U.P. Each farmer's field was also taken as replication for each machine. The technical programme of field evaluation of potato planting machines was designed in completely randomized on plot size: 1006 to 4800m^2.

Table 1 show the technical programme of the three types of potato planters which field performance was evaluated and description of the traditional manual potato planting method for comparison is also given in the Table 1. The Table 2 represents the specifications of tractor drawn potato planters.

Table 1: Potato planting method/machine used in field evaluation

S. No.	Machine/Method	Power source	Coded as
1.	Four row semi-automatic potato planter with rotary magazine	35 hp tractor	P1
2.	Two row semi-automatic potato planter with endless belt and fertilizer application unit	35 hp tractor	P2
3.	Two semi-automatic potato planter with endless belt without fertilizer application unit	35 hp tractor	P3
4.	Traditional method by using spade	Men	P4

Table 2: Specification of tractor drawn potato planters

S. No.	Description of planters	P1	P2	P3
1.	Name	Potato planter	Potato planter	Potato planter
2.	Make	Shehra Field Moga, Panjab	Basant Industries, Moga, Panjab	Isher Potato Machine, Meerut
3.	Model	4-row	2-row	2-row
4.	Overall dimension of planter only (L×W)	2770mm × 380mm	1780mm × 1470mm	1690mm × 1380mm
5.	**Furrow Opener**			
	a) Type	a) Shovel type	a) Shovel type	a) Shovel type
	b) Depth of potato planting	b) 170 mm	b) 170 mm	b) 170 mm
6.	Metering Mechanism			
	Potato			
	i) Type	i) Rotary magazine	i) Conveyer belt with cups	i) Conveyer belt with cups
	ii) No. of openings cups	ii) 9		
	iii) Drive Wheel	iii) Bevel gear	iii) Chain and Sproket	iii) Chain and Sproket
	iv) Speed ratio of shaft of seed metering drive	iv) 1: 1	iv) 1:1.29	iv) 1: 1.38
	Fertilizer			
	i) Type	—	Cell feed roller	—
	ii) No. of rollers per row	—	2.0	—
7.	Ground wheel detail			
	a) No, of wheels	a) 1	a) 1	a) 1
	b) Type of wheel	b) Lug type	b) Lug type	b) Lug type

	c) Size (Diameter)	c) 425 mm (adj.)	c) 407 mm (adj.)	c) 375 mm (adj.)
	d) Power transmitting method	d) Chain and sprocket	d) Chain and sprocket	d) Chain and sprocket
8.	**Operator's seat**			
	a) Type	a) Round	a) Rectangular	a) Rectangular
	b) Length & width/diameter	b) 335 mm	b) 840 X 230 mm	b) 840 X 230 mm
	c) Provision of foot support	c) No	c) yes	c) yes
9.	Type of hitch	Three point linkage type	Three point linkage type	Three point linkage type
10.	**Seed hopper**			
	a) Type	Rectangular (tapered base)	Rectangular (tapered base)	Rectangular (tapered base)
	b) Size	1214×234×415 mm	1020×690×500 mm	1050×700×500 mm
	c) Capacity	120 kg	100 kg	100 kg

The brief descriptions of evaluation procedure of the potato planting machine for their field performance are discussed below.

Evaluation procedure

The field testing of above described potato planters was done in the four villages on five farmers field and the area covered in each method was 4156, 11165, 8244 and 13271 m^2, managed by farmers. The observations were recorded with respect to the parameters of the soil, seed, machine and power source and tested. Three different methods of potato planters were compared with the conventional method of planting. The machine P1, P2 and P3 were operated with Swaraj 735 FE (35 hp), MF 1035 (35 hp) and Mahindra 365 DI (35 hp) tractor, respectively at 2nd low gear. In the last method (P4) the tubers were placed manually in rows on the soil surface at the spacing of 14 to15 mm followed by single earthing with the help of spade (Table 3).

Table 3: Details planting conditions and performance results of different potato planters and

Parameters	P1	P2	P3	P4
Test conditions				
(A) Condition of seed				
▪ Variety of potato seed	Kufri-Sutlej	Kufri-Sutlej	Kufri-Sutlej	Kufri-Sutlej
▪ Average size of seed ▪ (L×W× T) cm^3	4.17×2.9×2.57	4.88×3.59×2.84	4.29×3.57×2.90	4.03×3.97×2.77
▪ Average weight of tuber (gm)	26.35	33.40	29.50	30.10
(B) Condition of field				
▪ Total area (m^2)	4155.7	11165	8244	13271
▪ Type of soil	Silty loam	Silty loam	Silty loam	Silty loam
▪ Soil water content %	13.00	12.96	13.61	10.84
▪ Bulk density (g/cm^3)	1.35	1.32	1.43	1.37
(C) Condition of operation				
▪ Row spacing (cm)	60	62.5	60	56
▪ Average seed rate (kg/ha)	2601	3179	30.53	2736
▪ Depth of planting (cm)	16.67	16.33	13.5	12.8
▪ Fertilizer rate (kg/ha)	674	675	607	652
(D) Power source detail				
▪ Type	Tractor	Tractor	Tractor	Manual
▪ Make and model	Swaraj 735 FE	MF 1035	Mahindra 365 DI	NA
▪ Rated drawbar power (hp)	26.8	25.1	23.4	NA
▪ Selected gear	2nd low	2nd low	2nd low	NA
(E) Condition of operator				
▪ Skill of operator	Very good	Good	Average	
▪ Wage of operator (Rs/day)	72	72	72	
▪ Ambient temperature (db °C)	29.4	30.5	30.3	30.3
Field performance				
a) Total operating time (min)	101	490	412	
b) Total time lost owing to				
▪ Turning at head land (min)	58	66	12	
▪ Refilling of seed and fertilizer (min)	25	31	16	
▪ Adjustment and repair	—	—	—	
c) Actual area covered (m^2)	4155.7	11165	8244	13271
d) Effective field capacity (ha/hr)	0.25	0.13	0.12	
e) Speed of operation (m/min)	24.33	21.7	20.7	
f) Field efficiency %	70.41	81.03	80.5	
g) Width of head land (m)	3	3	3	
Slippage				
a) Tractor rear wheel %	15.78	8.30	8.90	
b) Potato metering drive wheel %	5.6	3.5	6.1	
Planting pattern				
a) Actual tuber spacing (cm)	14.67	15.38	15.44	14.33
b) Row to row spacing (cm)	60	62.5	60	55
c) Rate of missing %	6	5	3.5	—

d) Rate of doubling %	12.0	11.0	10.5	—
Size of bund				
a) Base width (cm)	50	50	48	46
b) Height (cm)	24.0	25.0	24.5	22
c) Top width (cm)	17.0	19.3	17.0	16.7
Fuel consumption (l/hr)	3.2	3.0	2.7	—
Yield of crop (t/ha)	31.86	30.45	30.66	26.78
Labour requirement				
a) Skilled	4.00	7.55	8.12	—
b) Unskilled	36.50	38.06	44.80	308.8
c) Total	40.5	45.56	52.92	308.8

The field preparation, except for semi-automatic potato planter with endless belt and fertilizer application unit, were done by two harrows operations. Total two harrows and four cultivators were used in the case of P1, P3 and P4 method while in P2 method three harrow and four cultivators were used for the field preparations. The date of sowing by each method was same for all the treatments at one location and there was not much difference in date of the sowing of other two locations.

Potato tubers used were chitted as well as un-chitted both types. However, farmer mostly cut the bigger tubers and then uses for planting purpose. The average length, width and thickness of the tubers used were varied as 40 to 49 mm, 29 to40 mm and 26 to 29 mm, respectively. However, the average weight of the tuber varied from 26 to 33 gm (Table 3).

The fertilizer applied as basal at the time of planting, varied from 607 to 675 kg/ha. The rest dose of fertilizer was applied as top dressing after the first irrigation. In the manually planted field, earthing was done manually by using spade fallowed by first irrigation. The irrigation was given in the furrows without distributing the ridges. Total three irrigations with diesel pumping set were given in all treatments and the germination count were recorded, for plant population, after 30 days of seeding at 4 to 6 leaf stage. The total production after harvesting was also recorded.

Measurement and Computation of different parameters

Operating speed: For calculating operating speed, time was recorded using stop watch to cover one end to other end length by the tractor under actual field condition for each operation separately. There after speed was calculated in km/hr.

Wheel Slip: The wheel slip was determined by making a point on the tractor and power tiller drive wheel with colored tape and measuring the distance traveled by the mark drive wheel for a particular number of revolutions under no load on the firm surface and with the same number of revolutions under the actual field operations. The slip was calculated in percent as given below:

$$Percent\ wheel\ slip = \frac{(A-B)}{A} X100$$

Where, A, the distance traveled by drive wheel under no load conditions in Known number of (say) revolution and B, the distance traveled by drive wheel under actual field operation in the same number of (say) revolutions.

Fuel consumption: For measuring the fuel consumptions the fuel tank was filled to full capacity before and after the test. The amount of refueling after the test is the fuel consumptions for that particular operation. When filling up the tank, careful attention was paid to keep the tank horizontally and not to leave empty space in the tank. For checking proper level to the tank sprit level was used.

Effective field capacity

The actual operating time along with time lost for every event such as turning, loading, unloading, adjusting, refueling and machine trouble were recorded for completion of a particular operation. The effective field capacity was calculated as follow:

$$C_E = \frac{A}{T_p + T_1}$$

Where, C_E is Effective field capacity (ha/hr), A is area covered (ha), T_P is Productive time (hr) and T_1 is Non Productive time (hr) (Time lost for turning, loading and adjusting, refueling and machine trouble)

Field efficiency: It was calculated as follows from the field test data.

$$E_f = \frac{C_T}{C_E} X100\%$$

Where, E_f is field efficiency (%),

$$C_T = \frac{SW}{10} X100\%$$

is theoretical speed (ha/h), S is average speed of travel, W is working width of equipment and C_E is effective field capacity (ha/h)

Bulk density of soil: Bulk density, the oven dried soil mass per unit volume, was measured with the help of cylindrical core sampler. Soil samples were taken randomly from three locations in each test plot and volume of soil samples was determined after measuring the diameter and length of core sampler. The samples were kept in oven at 105 ºC for about 12 hrs. Samples were taken out and weighed after their cooling and bulk density was evaluated as:

$$\text{Bulk density of soil (BD)} = \frac{\text{M}}{\text{V}} \text{g/cc}$$

$$= \frac{4\text{M}}{\pi \text{D}^2 \text{g}} \text{g/cc}$$

Where, M is mass of oven dried soil of core sampler (g), V is volume of core sampler (cm^3), D is inside diameter of core sampler (cm) and L is length of core sampler (cm)

Percentage missing of tubers: The number of planting

distances equal or more than twice the actual planting distance were considered the missing actual planting distance. They were counted in three meter length of row and calculated as the ratio of number of tubers in the distance near about twice of the planting distance and the total number of tubers planted.

Doubling percentage of tubers: The number of planting distances, having no distance or negligible distance between tubers estimated as doubling percentage of seed. It was calculated as the ratio of number of tubers having negligible tuber spacing and total number of tubers planted in 3m length of row.

Results and Discussion

Field evaluation test results of different types of potato planters *viz*. four row semi-automatic potato planter with rotary magazine (P1), two row semi-automatic potato planter with endless belt and fertilizer application unit (P2) and two row semi-automatic potato planter with endless belt without fertilizer application unit (P3) in comparison to conventional manual potato planting using spade (P4) are given in Table 3 and discussed under the subheads of machine aspect, crop aspect and economic aspect.

Machine aspect

Field performance

The potato planters P1, P2 and P3 were operated at 1.46, 1.3 and 1.25 km/hr forward speed with 35 hp tractors. The effective field capacity of these machines was 0.25, 0.13, and 0.12 ha/hr respectively while the corresponding field efficiency was 70.4%, 81.0% and 80.1% (Table 3). The operating speed of the semi-automatic potato planter with rotary magazine was high due to the very good skill of the operator. Effective field capacity of the semi-automatic potato planter with rotary magazine was highest due to the larger size of the machine. The semi-automatic potato planter with rotary magazine was of 4×60 cm size while semi-automatic potato planter with endless belt and fertilizer application unit and semi-automatic potato planter with endless belt without fertilizer application unit were of 2×62.5cm and 2×60cm size, respectively The efficiency of the planter P1 was 12.5% less in compression to the other two planting machines P2 and P3. Field efficiency of the machine P1 was less due to excessive slippage of the tractor rear wheel in the operation of P1, P2 and P3 machines. It was 15.8%, 8.3% and 8.9%, respectively, for P1, P2 and P3 (Table 3). The slippage on the tractor wheel was more for semi-automatic potato planter with rotary magazine due to it's bigger size which required more draft for it's operation. The slippage of the ground drive wheel of planting machines P1, P2 and P3 was 5.6%, 3.5% and 6.1% respectively (Table 3). The drive wheel slippage of P1 was more than P2 and P3 because former machine required operating four metering units.

Operation of semi-automatic potato planter with rotary magazine (P1) at higher speed caused problem in proper seed placement and excessive missing and doubling. Sometimes cups of rotary magazine were also found to be remaining unfilled. Table 3 also shows the missing percentage of the machine which varied from 5 to 6%, 4 to 5% and 3 to 4% in the planter P1, P2 and P3, respectively. Similarly, the doubling in the placement of potato tubers occurs from 10 to 12% in each of the planters (P1, P2 and P3). However, doubling in manual planting was very less and limited to 4 to 5% but there was no missing in the manual planting recorded. This may be due to the manual placement of potato tubers near at the equal interval. The calibrated seed tubers spacing for the planting machine P2 and P3 was 15.5 cm while in the planter P1 it was 14.5cm. It was observed that 64% of tubers are placed at the distance 10 to 20 cm spacing in the semi-automatic potato planter with rotary magazine (P1). In the semi-automatic potato planter with endless belt and fertilizer application unit 65% of the tubers were placed at 13 to 25 cm spacing and 68% within the range of 13 to 25 cm spacing. For semi-automatic potato planter with endless belt without fertilizer application unit 62% of tubers were placed at 10 to 20 cm tuber spacing. In the manual planting about 80% tubers were place at the tuber spacing of 8 to 18 cm (Table 3). The planting accuracy was more in manual planting due to precise placement of tubers with human concerns.

Average number of tubers planted per minute per ridge was of observed as 164, 140 and 134 tubers per minute per row respectably. The planting frequency of the planting machine P1 was more due to less calibrated tuber spacing and higher speed of operation. The base width, height, and top width of the bund formed by ridger bottom varied from 48 to 50, 24 to 26cm and 17 to 20 cm by planter P1, P2 and P3, respectively. The base width, height and top width of bund formed by manually by spade varied from 42 to 46cm, 20 to 24cm, 15 to 18cm respectively. The cross sectional area of the bund formed was 0.0.088, 0.081 and 0.069m^2 by the method P1, P2, P3 and P4 respectively. The cross sectional area of the bund was less in the case of manual planting. The depth of planting was 16 to 17 cm by method P1 and P2, and it was 13 to 14 cm by method P3. The depth of planting was 12 to 13 cm in case of manual planting. The size of bund made manually was smaller than P1, P2 and P3 hence it needed earthing at later stage. Labour Requirement: The semi-automatic potato planter with rotary magazine required seven persons for it's continuous operations, one persons for operating the tractor with machine, four sitting on the machine for placing and filling the seed tubers in rotary magazine and two persons for continuous filling of tubers in seed hopper.

Semi-automatic potato planter with endless belt and fertilizer application unit (P2) and without fertilizer application unit (P4) required six persons for continuous operation, one skilled persons for operating tractor and machine, four persons sitting on the machine for removing excess tubers or filling vacant cups and one persons for carrying and filling tubers and fertilizers in the machine during operation.

In the case of spade method of planting, one person make the furrow, one places the tubers, one cover the seed with soil all around and one person carry the seed and make available to the person who plants the tubers. However, in this case fertilizer was broadcasted by the same persons before seeding at the time of last operation of planting. The planting was done by 4-row, semi-automatic potato planter with rotary magazine (P1) on 4156 m^2 area. The skilled, unskilled and total man-hour required for P4, 32.5 and 36.5 respectively. The area planted by 2 rows, semi-automatic potato planter with endless belt with fertilizer application (P2) was 11165 m^2 It required 7.5 m-h/ha of skilled and 38 m-ha/ha of unskilled labour. The done with semi-automatic potato planters with endless belt without fertilizer application unit (P3) was done on 8244 m^2 area, which required 8 m-ha/ha skilled and 41 m-ha/ha of unskilled labour in planting operation. The planting done with planter P1 and P3, which have no fertilizer application devices, required extra m-ha for broadcasting

fertilizer before planting, about 4 m-ha per hectare were recorded for the broadcasting of fertilizer. The manual required 309 m-h/ha. It was the most labour consuming method of planting. There was 84 to 88% saving of labour while using any planter for planting the seed potato. In the manual planting by spade required 83m-h/ha for earthing operation, while there was no requirement of earthing in mechanical planting methods. There for the total labour saving is 87 to 90% by mechanical methods of planting. The manual method of planting required 309 man hrs/ha, it was the most labour consuming method of planting. There was 84 to 88% saving of labour while using any planter for planting the potato tubers. In the manual planting by spade required 83 m-hr/ha for earthing operation, while there was no requirement of earthing in mechanical planting methods. Therefore the total labour saving is 87 to 90% by mechanical methods of planting.

Crop aspect

The germination count (No. of plant/meter length in row) measured at 30 days (at 4 to 6 leaf stage) after planting was found 14, 10, 13 and 20m for the planters P1, P2, P3 and P4, respectively. The weed count was found the maximum in field planted by semiautomatic potato planter with rotary magazine, because of field conditions.

The yield recorded was 31.86, 27.76, 30.66 and 26.78 ton/ha by P1, P2, P3 and P4, respectively. It is clear from the Fig.1 that the yield was high from all the machines with respect to manual planting. The yield of the method P2 was recorded less due to high weed population in the field. The weedisides were also applied in the field; they lowered the weeds but not removed completely.

Economics

Table 4 represents the average planting cost of this experiment at farmer's field evaluated and observed that the varying cost of cultivation was highest in P4 (2769.60 Rs/ha) fallowed by P3 (1532.60 Rs/ha) and P2 (1485 Rs/ha) and lowest in P1 (836.20 Rs/ha). Thus, the farmer have invested 1237 Rs/ha more in case of spade method of planting than the most expensive method of mechanical planting. Therefore, there is a saving of 223.6%, 86.5% and 80.7% by planting method P1, P2 and P3 respectively in comparison to the manual method of planting with spade. The planting method P1 was found most economical because of larger machine size and consequently, the high field capacity of machine. The actual comparison between different machines P1, P2 and P3 is not possible due to the varying operator skills. But, it can be clearly said that any method of planting by potato planter is much economical in comparison to the traditional method of manual planting (Fig.1). The custom hiring charge of P1, P2 and P3 are 225, 210 and 200 Rs/hr with the tractor and labour.

Table 4: Total variable cost for different methods of planting

S No.	Particular	P1	P2	P3	P4
1.	Operating cost of machine (With Tractor) Rs/hr	202.05	193.05	180.55	—
2.	a) Cost of planting Rs/ha	808.20	1485.00	1504.60	2161.60
	b) Cost of fertilizer broadcasting Rs/ha	28	—	28	28
	c) Cost of earthing Rs/ha	—	—	—	580
3.	Total variable cost of cultivation	836.20	1485.00	1532.60	2769.60

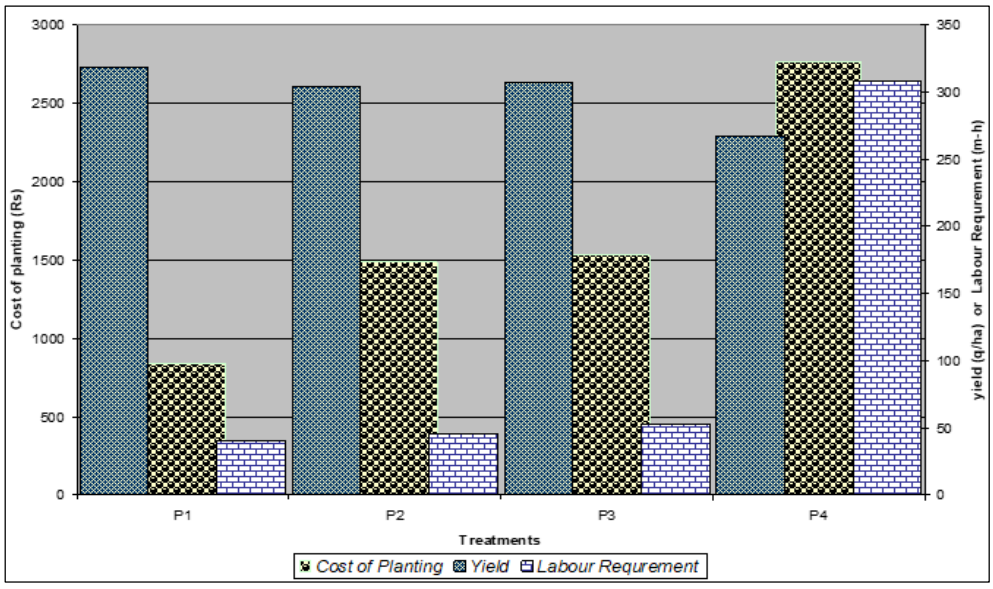

Fig 1: Performance of different potato planters

Constraints in the adoption of potato planters

Constraints in the adoption of semi-automatic potato planter were concluded on the basis of the facts reported by the farmers during thorough discussion on the field from crop showing to harvesting. The problems recorded in the adoption of the machines are listed below.

1. The initial cost of the planters found to be unaffordable for the small farmers. The procurement of the machine, thus, becomes difficult for them.
2. Lack of information/knowledge regarding the proper working and benefits of the machines is another big problem in the adoption. Consequently, most of the farmers have suspicion regarding the proper utilization of the planter, as, they have in their mind that in the manual planting tuber spacing would be more accurate and thus it could give higher yield.
3. The farmers with small land holding could not maintain a tractor and thus the planter too. They require custom hiring of these machines. But these machines are not available to them at the required time of planting which

instigates the feeling to plant manually.
4. There is a need of design modification of the planter so that it becomes more economical and suitable for soil conditions of Etawah district.
5. The farmers are not satisfied with the row to row spacing of the potato planter. The row to row spacing in manual planting is kept about 45 cm while the row to row spacing obtained through potato planters is about 60 cm. This gives strength to the farmer's thinking that the number of rows in potato planter is lesser than in manual plantation which would give low yield.

Conclusion

The tractor operated four row semi-automatic potato planter with rotary magazine (P1), the two row semi-automatic potato planter with endless belt with fertilizer application unit (P2) and the two row semi-automatic potato planter with endless belt without fertilizer application unit, the three potato planter, were used by the farmers of Etawah district. The specific conclusions of the current study are given below.

- All the Tractor mounted Potato Planter ridger were found cheaper in operation, labour saving (87 to 90%) and economical as compared to the traditional method of planting using spade and popular in this area.
- The plantation of potato by planter, also increased the yield by 19 to 10.5% (5.08 to 3.88 t/ha) than the spade method of planting. It is, therefore, clear by the field investigations carried out in this study that the planting potatoes with planters more profitable.
- The potato planters worked satisfactorily and gave no trouble in the field while operating.
- The potato planting with potato planters was less time consuming. The field capacity of the machines P1, P2 and P3 was 0.25, 0.13 and 0.12 ha/hr, respectively. The timely planting, thus, can be performed during the season using potato planters.
- The semi-automatic potato planter is the best option for the small and medium land holding farmers.
- The custom hiring charges of semi-automatic potato planters in the region was 200 to 225 Rs/hr.

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