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Development of a mini tractor drawn semiautomatic two row planter cum fertilizer applicator

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■ **ABSTRACT :** The potato planter is a very important machine, there is not much research available to show its effect on growth of plant or yield. But it proves its importance in time bounded operation, conservation and better utilization of energy, increased productivity of labour and overall precision in farm operations. Now days the majority of farmers are small and marginal and they cannot afford big sized tractors, so some cheaper mechanization for various farm operations is needed. Planting or sowing operation needs more accuracy than other farm operations, as costly seeds and fertilizer can be saved by using appropriate planting machine for respective crops. In fact, mini tractors are current demand for farmers as it can perform all the operations like big tractors with appropriate matching implement. By considering the above facts and to introduce a low cost appropriate technology for semiautomatic potato planter that can be operated by mini tractor, a mini tractor operated semiautomatic potato planter has been developed. The potato planter places potato tubers and fertilizer simultaneously at appropriate depth and the cost of operation of the planter is 1562 Rs./ha which is almost half (3285 Rs./ha) compared to medium sized tractor operated planter. So, the mini tractor drawn semi automatic planter is recommended for the farmers of planting of potato.

■ **KEY WORDS :** Mini tractor drawn semiautomatic, Two row planter cum fertilizer applicator

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The importance of machine is not well recognized as there is no visible effect of plant growth or yield. But it can surely be realized through timeliness in operation, low cost of operation, conservation and better utilization of energy, increased productivity of labour and precision in farm operations. Out of two methods of cultivation, the highest yield of tubers was obtained when potatoes were planted on ridges and spaced at 45 cm.

Smith *et al.* (1977) stated that the accuracy of planter depends upon the shape of hopper bottom and fullness of the hopper. A cone shaped hopper bottom causes seeds to gravitate into the cell, hence it should be preferred.

Swarnkar and Tripathi (1988) conducted study on design development and evaluation of G.A.U. bullock drawn potato planter for river bed potato crop. A bullock drawn potato planter has been developed for river bed cultivation of potato crop at G.A.U. The effective field capacity of planter was 0.20 ha/day at speed of 1.44 km/h and row to row spacing of 20 cm. Net financial saving over to conventional method was Rs.1242 per hectare.

Ahuja and Bhatia (2002) conducted study on usage and field performance of automatic potato planters in India with row to row and plant to plant spacing of 60 cm x 20 cm. They used third low or 1st high gear and achieved average field capacity 8-10 acres/day with 60-80 per cent field efficiency as well as the planter saved labour by 60 per cent in comparison to semi automatic machine.

Mari *et al*. (2002) conducted study on evaluation of tractor operated potato planter. The parameters were determined at moisture content of 15.73 per cent, fuel consumption was 24.04 l/ha. The travel reduction was 5.04 per cent field efficiency was 67.47 per cent, field capacity was 0.80 ha/h. They suggested farmers to plant more potato by using potato planter, because it covers more area in less time. It was labour saving machine.

The majority of farmers of the region are small and marginal and they cannot afford big sized tractors, so some cheaper mechanization for various farm operations is needed.

Planting or sowing operation needs more accuracy than other farm operation as costly seeds and fertilizer can be saved by using appropriate planting machine for respective crops.

In fact, mini tractors are current demand for farmers as it can perform all the operations like big tractors with appropriate matching implement.

Planters for maize, wheat, cotton etc. has been extensively used by the farmers but the planter for potato crop is still not popularized among farming community.

It is a big duty of researchers to introduce a low cost appropriate technology for automatic or semiautomatic potato planter that can be operated by mini tractor.

So, by considering the above points and reviews, a mini tractor operated semiautomatic potato planter has been developed at Department of Farm Machinery and Power Engineering, College of Agricultural Engingeering and Technology, Godhra.

■ METHODOLOGY

Design considerations of two row semi-automatic potato planter:

The technique and procedure to design the potato planter includes design of the major components of the planter *viz.*, seed hopper, metering device, shafts, power transmission wheel, chain and sprockets, seed tubes, furrow openers and frame are summarized and given below:

Seed hopper:

On the basis of reviews and studies of physical properties of potatoes, the average bulk density of potato seed was 650 kg/m^3 and the angle of repose 37° was taken for designing the seed hopper and capacity of the hopper was kept 65 kg with volume of hopper as 0.1 cubic meter (Fig. A).

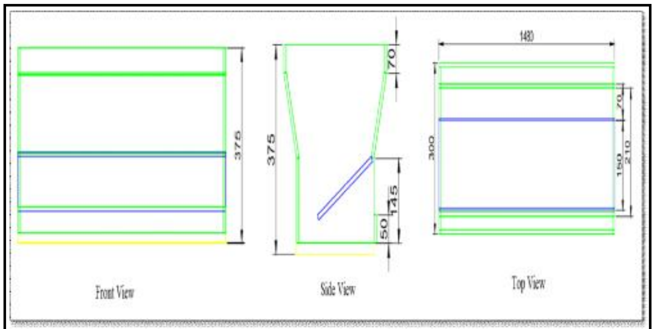

Fig. A: Seed hopper

Seed metering device :

This is the most important part of the planter as it determines the proper metering of the seed. So, an appropriate kind of horizontal disk made from aluminum having 357 mm diameter was used to work as metering disc and nine cells were provided on the periphery of each metering disc. The dimensions of each cell were

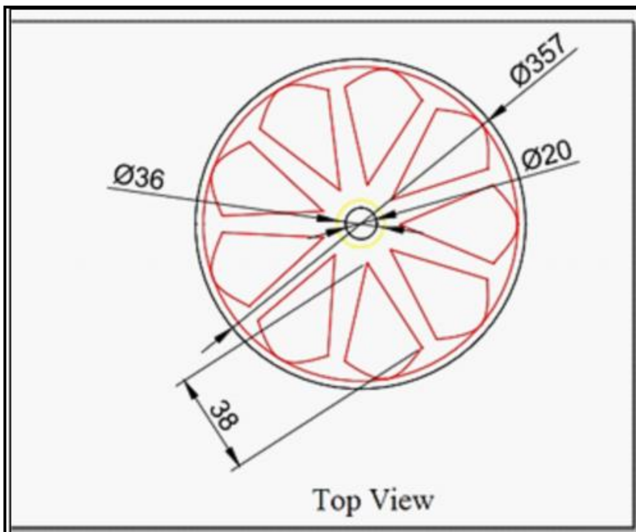

Fig. B: Potato planter seed metering plate

decided by taking into account the dimensions of the potato seeds so as to accommodate maximum size of potato seeds in the cells (Fig. B).

Fertilizer metering mechanism:

Potato crop requires huge amounts of fertilizers (kg/ha) *viz.,* N-P-K : 200-100-200, respectively and even more dozes are applied by the farmers. To provide recommended doses of above fertilizers following chemical fertilizer are available in the market: Urea, N P K, DAP, muriate of potash etc. Depending on the use of different brands of the chemical fertilizers the fertilizer requirements ranges from 500- 800 kg/ha. To meter the huge amount the design of fertilizer metering was carried out separately.

The fertilizer metering mechanism for mini tractor drawn potato planter consists of following components:

Fertilizer hopper:

Looking to the hopper for potato seed (65 kg), volume of the fertilizer hopper was designed in such a way that fertilizer feeding was carried out once for two or three times feedings of potato seeds. On the basis of reviews and studies of physical properties of fertilizer, the average bulk density of fertilizer was 800 kg/$m^3$and the angle of repose of 38° was taken for designing the fertilizer hopper.

As the angle of repose of fertilizer was 38°, therefore, the angle of the hopper side wall was kept greater than 38° (it was kept 43°). This angle facilitated the smooth flow of fertilizer under the gravitational force towards the metering mechanism. The overall capacity of the hopper was kept 32 kg of fertilizer (having volume of @ 40200 cm^3). The volume of the hopper was determined on the basis of average bulk density (800 kg/m^3) of the fertilizer.

The length of the hopper was taken as 1/3rd of potato seed hopper and on the basis of length, volume, angle of repose following dimensions of hopper were worked out.

Length of hopper = 500 mm, top width of hopper = 300 mm, bottom width of hopper = 80 mm and height of hopper = 500 mm.

Fertilizer metering device:

Fertilizer metering device has been designed to meter the huge amount of fertilizer requirement of potato crop. Max. Requirement of fertilizer for one hectare is 800 kg and for one square meter area mass of fertilizer required is 80 g. Density of fertilizer = 0.8 g/cm^3 volume of fertilizer required per sq.m = mass of fertilizer /density of fertilizer = 80 / 0.8 = 100 cm^3 /m^2

If D is the diameter of drive wheel and W is the row to row distance of potato planting then, area covered in one revolution of ground wheel

(®D × W = 3.14 × 0.52×0.6= 0.9796 m^2 ù 1 m^2)

As the fertilizer metering mechanism was designed for two rows, two fertilizer metering rotors were provided. Fertilizer metering device was vertical feed cup type rotor with cells on its periphery. It was made of HDPE plastic material with the depth of 34 mm to facilitate for fertilizer. The outer diameter of rotor was 94 mm. The diameter of inner side of rotor was 60 mm with 70 mm width of rotor. The rotor had 6 cells arranged on its periphery.

Design of main shaft:

The seed metering mechanism, fertilizer metering mechanism and ground wheel as a whole consists of 6 shafts one each for metering roller, transmission wheel and intermediary hinges. The diameter of shaft was taken 20 mm as per the availability of the material and similar diameter was used for other four shafts as same amount of torque is to be transmitted.

Power transmission wheel:

It was observed that the diameter of power transmission wheels used for seed drills/planters ranges from 30 to 70 cm. Verma (1986) suggested diameter of power transmission wheels as 22.5 to 40 cm for bullock driven planter and 40 to 60 cm for tractor driven planter. In order to adjust the number of cells and plant spacing, the diameter of power transmission wheel was also made adjustable and was taken as 52 cm in present study. The dimension of rim, hub and number of peg were decided as follows:

Rim :

Rim width of ground wheel was chosen 40 mm as it ranges from 30 to 50 mm in case of planter and the thickness of rim (T) was 6 mm.

Hub:

The inner diameter of hub was taken equal to the diameter of the shaft *i.e.* 20 mm. Two hubs were provided and fitted on the main frame to support both the end of the shaft.

Peg:

On the periphery of ground wheel 6 pegs of length 110 mm and width of 50 mm were provided to avoid slippage of ground wheel during operation.

Chain and sprocket:

A bike chain was selected for transmitting power from ground wheel to metering roller. The arrangement was such that it had three sprockets of 20 teeth. The centre distance, number of links and length of chain were decided as 350, 76 and 950 mm, respectively (Fig. C).

Frame and hitching system:

A 50 x 50 x 5 mm M.S. square section was selected to make the frame and hitching system of the potato planter. The details of the frame is given in the Fig. D.

Seed tube:

A PVC tube with an inner diameter of 76 mm was selected. The length of seed tube was kept 210 mm.

Furrow opener:

A shovel type furrow opener was found most suitable for this planter because the shovel has to work in the tilled soil to form a furrow of sufficient width to facilitate proper placement of potato seeds and shovel type furrow openers forms a good furrow (Fig. E).

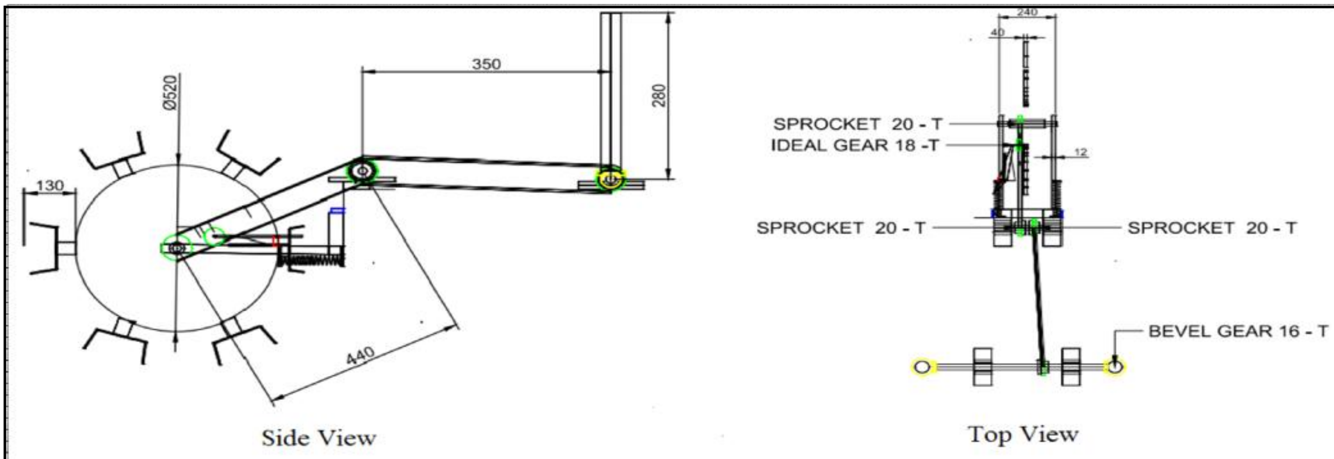

Fig. C: Ground wheel and power transmission

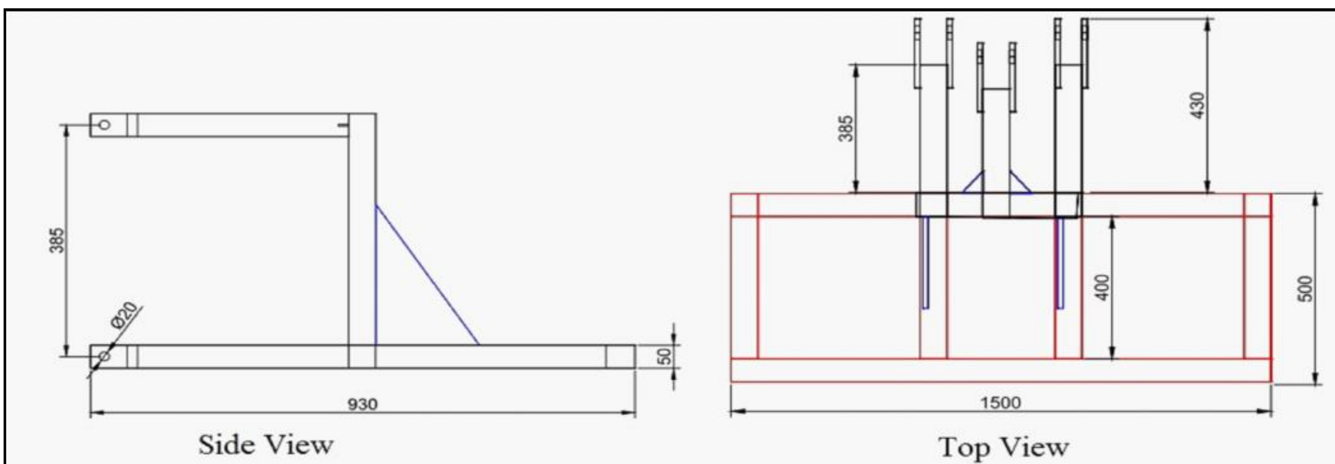

Fig. D: Frame and three point hitching system

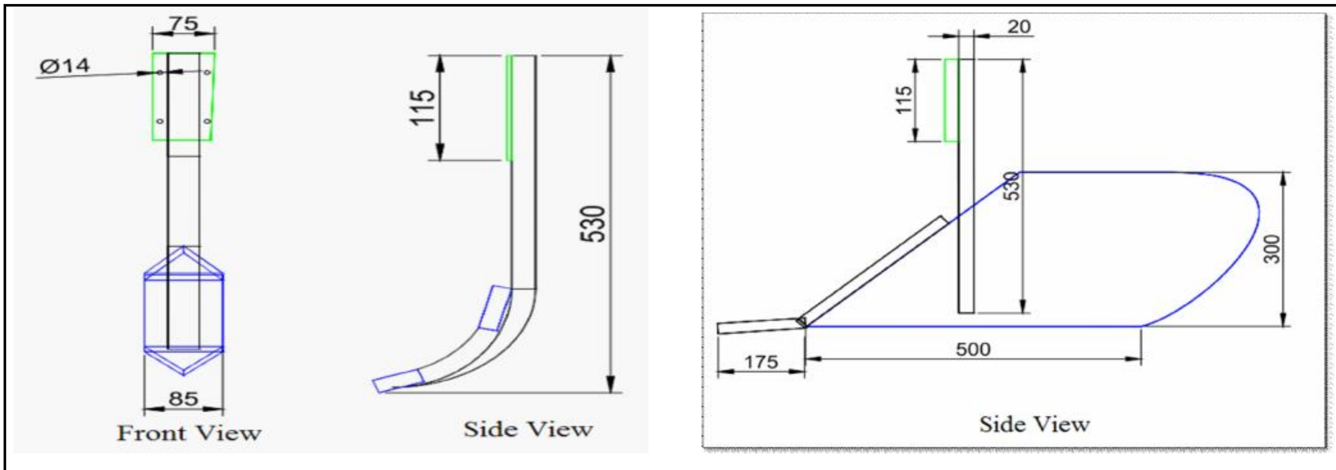

Fig. E: Furrow opener and ridger

Ridger:

Ridger were procured from the market with adjustable wings and medium size to form ridges of recommended dimensions as per the data of the survey revealed the dimensions as follows: Top width of ridges was varying from 15 to 25 cm, bottom width of ridge was varying between 35 to 40 cm and height of ridges was varying from 15 to 20 cm.

Fig. F : Developed prototype of two row semiautomatic potato planter

Fig. G : Developed prototype of two row semiautomatic potato planter under operation

Performance evaluation of potato planter:

For operating the potato planter with fertilizer metering mechanism in the field, three point linkage of planter was attached to the mini tractor with the help of pin. Seed hopper filled with good quality of potato seeds and fertilizer hopper filled with mixing of N P K fertilizers. The whole unit was taken to field having well prepared seedbed. During operation, the ground wheel rotated, thereby metering shaft was also rotated through counter shaft with the help of chain and sprocket. The fertilizer metering mechanism metering rotor shaft were also rotated along with the metering shaft.

To determine the fertilizer dropping rate obtainable at different hopper capacity and the variation among furrow openers when the machine was stationary. Series of tests were conducted for fertilizer dropping was conducted and recorded as under Table 1.

Seed distribution among furrows:

In the laboratory furrow to furrow variation in seed metering at different seed type was studied and results indicated that the maximum deviation of seed discharge of any furrow openers from the average was observed to be less than 2 per cent at different seed type. All the variations were within the range of 7 per cent as set by Indian Standards. Hence, it can be concluded that planter performed satisfactory in metering potato seeds with in rows and shown in Table 1.

RESULTS AND DISCUSSION

The results obtained from the present investigation as well as relevant discussion have been summarized under following heads :

Seed germination in the laboratory:

For seed germination test, the seeds collected during calibration were tested for the germination. The germination (%) of potato seed was found as 84.33 and 81.33 per cent for unmetered and metered, respectively.

Field tests of the planter:

Soil properties of the seedbed:

The mean data on soil moisture content after tillage operations at 0 to 20 cm depth recorded at 0 to 20 cm depth were 13.32 per cent and bulk density as 1.17 g/cc.

The clod mean-mass-diameter is an index for indirect measurement of tilth of soil. It has been indicated that soil aggregates of size 12 to 14 mm in the final seedbed are adequate for sowing crops. In the testing field MMD was found as 10.32 mm.

Depth of seed placement:

The average placement of seeds in all the furrows opened by the planter was 6.94 cm.

Row to row spacing:

The distance of row in all furrows by the planter is shown Table 2. The distance between rows was 60.5 to 62.0 cm and average distance was 61.1 cm and it did not vary between the ridges, which indicate the ridges are uniform (Table 2).

Height and width of ridge:

The height and width of the ridge in all ridges by

Fig. 1 : Potato planter under operation

Table 1 : Seed uniformity, percentage of missing and percentage of doubles

Speed (km/h)	Seed type	Avg. spacing bet. two consecutive seeds (cm)	Co-efficient of uniformity (%)	Number of missing	% of missing	Number of double	% of double
	Whole	18.26	85.4	2	7.41	3	11.11
2.1	Whole	18.30	85.2	2	7.41	3	11.11
	Avg.	18.28	85.3	2.0	7.41	3	11.11
	Whole	18.22	85	2	7.41	3	11.11
2.7	Whole	18.15	84.5	2	7.41	3	11.11
	Avg.	18.19	84.75	2.0	7.41	3	11.11
	Whole	18.22	79.7	3	11.11	4	14.81
3.4	Whole	18.04	80.3	2	7.41	3	11.11
	Avg.	18.13	80	2.5	9.26	3.5	12.96

Seed uniformity, percentage of missing and percentage of doubles (Length of furrow = 5 m)

Fig. 2 : Measurement of seed and fertilizer placement

the planter is shown in Table 2. The height of ridge was 21 to 22 cm and average distance was 21.16 cm and it did not vary between ridges, which indicate the ridges are uniform. The bottom width of ridge was varying from 45 to 46 cm and average width was 45.4 cm and it did not vary between the ridges, which indicate the ridges are uniform.

Draft and power requirement:

The data regarding the effect of different speed on the draft of planter are presented in Table 3 which indicated that the draft of the planter and speed of the planter are proportionate to each other. Maximum draft 314 kgf was observed at speed of 3.4 km/h followed by 309 kgf at speed of 2.7 km/h and 292 kgf at speed of 2.1 km/h. As speed increased volume of the soil mass per unit time through the planter was increased and therefore, soil resistance was also increased which resulted into draft value. Power requirement to operate tractor at load condition was also determined and shown in Table 4. More power (hp) was required at higher speed which was 4.06, 3.09 and 2.37 at the speed (km/h) of 3.4, 2.7 and 2.1, respectively. The tractor requires more power at higher speed due to overcome more resistance developed at tractor and at working place.

Wheel slipage:

The data regarding the effect of different speed on the wheel slippage are presented in Table 3. Wheel slippage increased as the speed increase. Maximum wheel slippage was 12.11 per cent at the speed 3.4 km/h followed by 10.49 per cent at speed of 2.7 km/h and

Table 2 : Height and width of ridge and row to row spacing

Sr. No.	Row to row spacing (cm)	Height of ridge (cm)	Bottom width of ridge (cm)	Top width of ridge (cm)
1.	61.5	21.2	45	15
2.	60.3	20.6	45.5	14.7
3.	60.5	22	45.5	15.3
4.	61.3	20.5	45.2	15.1
5.	61.7	21.5	45.8	14.8
Avg.	61.06	21.16	45.4	14.98

Table 3: Overall observations during performance evaluation of planter **(The width of planter was 1.2 m)**

Speed (kmph)	TFC (ha/h)	EFC (ha/h)	F.E. (%)	Draft (kgf)	dbhp (hp)	Fuel (l/h)	Slipage (%)	Man-h /ha	Seed rate (kg/ha)	Fertilizer rate (kg/ha)	Mechanical damage (%)	Cost of operation (Rs./ha)
2.1	0.252	0.197	78.25	292	2.33	1.08	9.41	11.55	2309	725.75	0.61	1020
2.7	0.324	0.244	75.30	309	3.09	1.15	10.49	9.21	2284	714.39	0.65	838
3.4	0.408	0.298	73.03	314	4.06	1.42	12.11	7.14	2256	689.39	0.69	732

Plot size = 30×3.6 m, Soil moisture content = 13.32 %

9.41 per cent at speed of 2.1 km/h. As 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 resistance on the traction wheel.

Fuel consumption:

The data regarding the effect of different speed on the fuel consumption are presented in Table 3. Fuel consumed by the prime mover with the planter per unit area (l/ha) decreased as speed of the operation increased. Minimum fuel consumption 6.34 l/ha was observed at speed of 3.4 km/hr followed by 7.33 l/ha at speed of 2.7 km/hr and 8.19 l/ha at the speed of 2.1 km/hr. As speed increased the field capacity increased because at higher speed more area per unit time was covered hence, fuel consumption per unit area decreased. Generally fuel consumption per unit time is increased as speed of operation increased but in this case more area is covered per unit time at higher speed which is more effective factor in reduction of fuel consumption per unit area.

Time and man-power requirement:

The data regarding the effect of different speed on the time to cover 1 ha area are presented in Table 3.

The data regarding the effect of different speed on the time to cover 400 m^2 and one ha area are presented in Table 3. Time consumed by the prime mover with the planter per unit area (ha) decreased as speed of the operation increased. Minimum time 7.14 hr. was observed at speed of 3.4 km/hr followed by 9.21 hr. at speed of 2.7 km/hr and 11.55 hr. at the speed of 2.1 km/hr. As speed increased the field capacity increased because at higher speed more area per unit time was covered hence time per unit area decreased. The data presented in Table 3, showed the effect of different speed on labour requirements. The speed 3.4 km/hr resulted 7.14 man-h to cover 1 ha that was lower followed 9.21 man-h/ha at speed of 2.7 km/hr and 11.55 man-h/ha at speed of 2.1 km/hr. The speed 2.7 km/hr had also lower time as compared to 2.1 km/hr.

Fig. 3 : Measurement of height of ridge

Fig. 4 : Measurement of draft

Fig. 5 : Measurement of wheel slippage

Fig. 6 : Measurement of fuel consumption

Speed of operation:

The speed of operation (km/h) were recorded as 2.1, 2.7 and 3.4. We selected 2.7 km/hr speed because of less slippage and less power requirement as compared to 3.4 km/hr. The speed 2.1 km/hr was also suitable for operation but it required more time and fuel consumption so 2.7 km/hr is more suitable for operation.

Power requirement:

Power required to draw potato planter with fertilizer metering mechanism was calculated as below: We had driven tractor on the speed 2.1, 2.7 and 3.4 km/h and draft (kgf) were 292, 309 and 314 and thus, the power (hp) were calculated as 2.33, 3.09 and 4.06, respectively.

Theoretical field capacity, effective field capacity and field efficiency:

The data regarding the effect of different speed on the theoretical field capacity, effective field capacity and field efficiency to cover 1 ha area are presented in Table 1.

Table: Theoretical field capacity, effective field capacity and field efficiency

(Size of plot = (30×3.6) m^{2-}, Width of planter = 1.2 m).

Field performance of fertilizer metering of a planter:

Placement of fertilizer:

The two row semi-automatic potato planter with fertilizer metering mechanism attached was tested in the field to determine the placement of fertilizer, also. The placement of fertilizer requires prior to seed placement. The depth of fertilizer placement was found 0.5 to 1.5 cm below the potato seeds dropped by the planter. Hence, a layer of soil was maintaining between fertilizer and seed placement as shown in figure.

Fertilizer rate of planter:

The data collected during field calibration are presented in Table 1. The fertilizer rate (kg/ha) obtained in the field calibration was in the range of 650 to 750.

Table: Fertilizer rate test in field (Variety of fertilizer = NPK, DAP, urea.

Economics of operation:

Results show that, as speed increased the field capacity increased because at higher speed more area per unit time was covered hence fuel consumption per unit area decreased due to this cost of operation also decrease. The fabrication cost of the planter was obtained Rs. 25805 by considering prevailing rates of all the required material. The total cost of planting operation was worked out by considering the fixed and variable costs. Minimum cost of operation 732 Rs./ha was observed at speed of 3.4 km/hr followed by 838 Rs./ha at speed of 2.7 km/hr and 1020 Rs./ha at the speed of

Table 4: Comparative performance evaluation of mini tractor drawn semi automatic potato planter with medium sized (45 hp) tractor operated two row semi automatic potato planter

	Mini tractor operated planter			Medium size tractor operated planter		
Speed of operation (km/h)	2.1	2.7	3.4	2.1	2.7	3.4
Fuel consumption (lit/h)	1.08	1.15	1.42	1.50	1.65	1.95
Fuel and lubrication cost (Rs./h)	70.2	74.75	92.3	97.5	107.25	126.75
Theoretical field capacity (ha/h)	0.252	0.324	0.408	0.252	0.324	0.408
Effective field capacity (ha/h)	0.197	0.244	0.298	0.230	0.255	0.312
Field efficiency (%)	78.25	75.30	73.03	91.26	78.70	76.47
Cost of operation (Rs./h)	201.00	204.5	218.00	379.25	389.00	408.50
Cost of operation (Rs./ha)	1020	838	732	1649.00	1525.50	1309.30
Saving (%)	38.14	45.06	44.09	-	-	-

2.1 km/hr (Table 4). As speed increased the field capacity increased because at higher speed more area per unit time was covered hence, fuel consumption per unit area decreased due to this cost of operation also decreased. The per hectare operational cost was compared with the planting operation of medium sized tractor (45 hp) drawn semi automatic planter at three speeds.

The following values were considered/ assumed for cost estimation during planting operation:

Life of tractor = 10 years, Annual working hours of tractor = 1000 h, Initial cost of medium sized tractor, C = Rs. 5,50,000, Initial cost of mini tractor, C = Rs. 2, 50,000, Initial cost of planter for medium size tractor, C = Rs. 60,000. Initial cost of proto type planter, C = Rs. 25800, Life of planter = 8 years, Annual working hours of planter = 300 h, Salvage value S = 10% of C, Rate of interest =10% Housing and Taxes and insurance = 3% of C, Repair and maintenances = 10% of C, Fuel price = Rs. 50/ltr, Lubricant cost = 30% of Fuel cost, Labour cost =Rs. 200/8h, The parameters were calculated on the basis of above data.

Conclusion:

The cost of the planter was worked out to be Rs. 25805 and it is found Rs. 60000 in case of such type of medium sized tractor operated planter.

The average depth of seed was 6.94 cm and it did not vary between the furrow openers, which indicated that the placement in the furrow openers were uniform. According to Ram (1975) the depth at which the seed must be planted to enable to get contact with a sufficient moist layer in order to ensure germination is generally 5 to 10 cm.

The placement of fertilizer was takes place prior to seed placement and depth of fertilizer placed was found 0.5 to 1.5 cm below the seed placement.

The average rate (kg/ha) during field calibration was found to be 700 which were under the limit of recommended fertilizer rate by Anand Agriculture University.

Cost of operation decreased as speed of the operation increased. It was observed that the cost of operation per ha was Rs.1020 at the speed 2.1 km/hr followed by Rs. 838 at speed of 2.7 km/hr and Rs.732 at speed of 3.4 km/hr.

The cost of planting operation per ha in case of medium sized tractor was Rs.1529 at speed of 2.1 km/ hr, Rs.1416 at speed of 2.7 km/hr and Rs.1220 at the speed 3.4 km/hr.

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