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Adaptation and Evaluation of Two row Tractor Drawn Potato Planter

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ABSTRACT

Potato is one of the major staple food items in Ethiopia. This crop is providing excellent opportunities in raising the income of farmers. This also provides higher productivity and offers great scope for value addition. However, manual planting consumes more time and labour. To overcome this problem, a tractor drawn automatic row planter was developed. The developed mini tractor drawn potato planter consists of hopper, cup seed metering mechanism, furrow opener, ground wheel and furrow covering device. The performances of the potato planter were evaluated in the laboratory and field evaluation were conducted to study the effect of planter forward speed and hopper filling level on various dependent parameters like missing index, multiple index, precision index and quality of feed index. The study also revealed that speed of operation significantly affected mean seed spacing, multiple index, missing index, precision index and quality of feed index. The mean spacing index value ranged between 30.39 cm to 37 cm with increase in forward speeds. The multiple indexes and miss index ranged from 9.65% to 12.35% and 12.35 % to 22.70% respectively. A larger value of missing index at higher speeds can be attributed to higher cup velocity which gives little time to the seeds to fill up in the cups. Quality of feed index was ranged from 66.25% to 76% and the value of precision index was obtained in the range of 14.63 to 19.45%. The mean value of theoretical field capacity, effective field capacity and field efficiency of the machine were 0.180 ha/hr, 0.15 ha/hr and 82.13 % at 1.5 km/hr forward speed respectively. The average depth of seed placement was found 7.04 cm. Based on the performance evaluation results, it is concluded that the tractor drawn automatic potato planter is satisfactory and can be subjected to further modifications at the seed metering mechanism so as to minimize the production cost the machine and seed damage.

Keywords: Field Capacity; Field Efficiency; Furrow Covering; Hopper Filling; Metering; Missing Index; Multiple Index; Precision Index; Quality of Feed Index; Speed.

1. Introduction

1.1. Background

Agriculture contributes significantly in Ethiopian economy. Ethiopian's economic progress of a nation is very important for the development of its citizen and Ethiopia being the country with increasing of population dependent on agriculture for livelihood can only prosper, if agriculture is sustainable. Farm equipment are used in farming operations to increase productivity of land and reducing labour requirement with timeliness in operations, for efficient use of inputs. Besides producing cereal, pulse and other crops, vegetable crops also play an important role in the self-food security.

Potato is an important cash crop, which can be cultivated in wide range of soils and weather conditions. It is the fourth most important staple food items in the world (Hakan Kibar, 2012). It provides high nutrition and an adaptive species for climate change. Potatoes use less water for nutritional output than all other major food sources and can be grown across Africa (Vita and IPF, 2014). Potato plays an important role in improving food security and cash income of smallholder potato growers in Ethiopia. Planting has been accomplished by traditional methods to planting the potato tubers on the field, which is a labor intensive, time consuming and low yield of potato per hectare.

Planting is the process of placing seeds in the soil to have good germination. It is one of the most important cultural practices associated with crop production. An exercise which should result in plant stands at the desired density that emerges quickly and uniformly. A good seed planting gives the correct amount of seed per unit area, correct depth at which seed is placed in the soil and correct spacing between row-to-row and plant-to-plant. This is a key factor for efficient harvesting in a mechanized establishment. Uniform seed distribution within the soil results in better germination and emergence increased yield by minimizing competition between plants for available resources such as light, water, and nutrients. A number of factors affect seed distribution in soil such as the seed metering system, seed delivery tube, furrow opener design, physical attributes of seed, and soil conditions (Karayel et al., 2008).

In Ethiopian farmers are inspired in potato cultivation because of high demand in market and its comparatively high price. Looking to present situation of the potato in Ethiopia, it is noticed that the level of productivity is very low. The production of potato can be enhanced by adopting different measures such as increasing area under cultivation, use of improved high yielding verities, supplementing with nutrient requirements, adopting appropriate plant protection measures and efficient machinery for its cultivation.

Regarding the benefit of potato to human being for consumption and as well for self-food security, there is need to increase the planting rate of potato in the country which is necessary to produce more potato, and will only be achieved by employ farm mechanization. The Manual method of planting seed, normally result to low placement of seed, spacing efficiencies and severe ache for the farmer that reduces the magnitude of farmland to be planted. So, the use of planter which is essential to make more food is beyond the capacity of small-scale farmers. It is very important to develop a planter with low cost that will decrease the hard labour to farmers, enable them to maximise their farm size. Therefore, this study was aimed and initiated with the objective of adaptation and evaluation of two row automatic mini tractor drawn potato planter.

1.2. Research Objectives

Adaptation and evaluation of two row Tractor drawn potato planter.

2. Materials and Methods

This chapter deals with the technique and procedure of development of mini tractor operated two row automatic potato planter with design aspects of various components and constructional details and methodology of testing the potato planter in the laboratory as well as in the field. The materials used to develop the planter and equipment used to test the row planter has been discussed under respective title.

2.1. Description of the machine

The developed automatic potato row planter was designed as a three-point hitch mounting type machine consisting of major components of frame, seed hopper, metering device, shafts, power transmission wheel, chain and sprockets, seed tubes, furrow openers and cover. The details of each component are given below:

2.1.1. Frame

The main frame was made with a mild steel rectangular tubular section of dimensions 50 mm x 50 mm x 5 mm. It supports all other components of the planter. A three point hitch assembly is used to hitch the planter with the tractor. The frame and other component parts of the planter were made using appropriate bolts and nuts.

2.1.2. Seed hopper

The seed hopper was designed considering the bulk density and angle of repose of potato seed as 650 kg/m^3 and 35.5° respectively (Sagni Bedassa, 2019). The capacity of the hopper was determined considering following factors. Row to Row distance: 60 cm, Plant to plant spacing: 30 cm and Seed rate (assumed): 2300 kg/ha.

The volume of the hopper was determined on the basis of average bulk density (650kg/m^3) of the potato seeds (Olaoye and Bolufawi, 2001):

$$V = \frac{S_R}{n \times BD} \quad \ldots(1)$$

Where: - S_R = seeding rate (kg/ha), n = number of refilling per hectare, B_D = bulk density of the seeds (kg/m^3).

$$V = \frac{2300}{35 \times 650} = 0.1m^3 \quad \ldots(2)$$

The Length of the hopper was taken as length of the frame and on the basis of length, volume; angle of repose the hopper has trapezoidal shape vertically having 350 mm and 200 mm rectangular width at top and bottom respectively and 1200 mm length. The height of the hopper is 400 mm.

2.1.3. Power transmission

The power is transmitted from the ground wheel shaft to a shaft fitted above the main frame by a chain and sprocket with speed ratio 1:2. The driven shaft is supported by the main frame with necessary support arms. The drive is transmitted from the shaft to the potato metering cup of driven shaft through chain and sprocket.

2.1.4. Ground wheel

The ground wheel diameter was selected on the basis of ground clearance that is available below the seed box. Since the ground wheel was more concerned for supporting the planter and its movement along with the planter and for power transmission, main focus was given on the width of the wheel, so as to prevent its sink age into the soil. A sheet of 80mm width and 3mm thickness was selected and 60cm wheel diameter was used. The ground wheel was fitted to the mainframe with shaft and supporting frameworks.

2.1.5. Metering mechanism

The seed metering mechanism of the potato planter is a cup type vertical drive. As the tractor moved forward the seed-metering device was rotated by a chain-sprocket arrangement through drive wheels. Seed to seed spacing is regulated by the rate of rotation of the seed-metering sprocket. The metering sprocket rotation i.e. the seed spacing of potato was maintained by the planter drive wheel diameter and the size of sprockets attached to the planter drive wheel and shaft of the seed-metering sprocket. The number of cups was determined by the following equation (Momin, 2006):

$$S_P = \frac{\pi D T_2}{n T_1} \quad \ldots(3)$$

Where: - Sp = Seed to seed spacing of potato in the field (0.3 m), D = Diameter of the planter drive wheel (0.6 m), T_1 = Number of teeth of the sprocket attached to the planter drive wheel axle (15), T_2 = Number of teeth of the sprocket attached to the seed metering axle (30), n = Number of cups.

From equation 2, $n = \frac{\pi \times 0.6 \times 30}{0.3 \times 15} = \frac{56.55}{4.5} = 12.57 \approx 13 cups$

2.1.6. Furrow opener

After a study of various available furrow openers, it was decided on the basis of the soil type that a shovel type furrow opener would be most suitable for tilled soil to form a furrow of sufficient width to facilitate proper placement of potato seeds. A shoe type furrow opener was attached to the main frame below the seed hopper at a distance of 60 cm. The shank was made from a 12 mm thick flat bar. The wing was made from 4 mm thick mild steel sheet metal. The wings were welded to the shank of mild steel that was fixed to the frame of the planter so that furrows are opened and potato seeds are dropped at the bottom of furrow. The depth of seed placement can be varied by adjusting the height of furrow opener shank upwards or downwards.

2.1.7. Ridger

The ridger is used for covering the dropped seeds. The soil lifted and thrown by the wings of the ridgers and cover the dropped potato seeds at the rear. The ridges wing could be adjustable based on required ridge width.

2.1.8. Seed delivery chute

The metered seed has to be transported to furrow bottom. Chute sizes of 90 cm length and 15 cm diameter were provided from the bottom of the seed metering unit.

2.2. Working principle of potato planter

For operating the potato planter in the field, three point linkage of planter was attached to the tractor with the help of pin. Seed hopper filled with good quality of potato seeds and as the planter moves forward, the chain and cup assembly starts moving through the seed hopper in which seeds are stored. As the chain moves up it carries seeds in the cup, which are located at same distance from each other. As the chain moves further up the cup gets inverted inside a chute which drops the seed to the ground. At the same time the furrow opener opens a furrow in which the seeds are planted. As the planter moves further, the ridger attachment then covers the seeds and makes a ridge.

2.3. Performance Evaluation of Potato Planter

In order to evaluate the performance of the potato planter, it is essential to check it with respect to seed rate, mechanical damage, seed distribution, seed placement, power requirement, field efficiency and fuel consumption. It was evaluated for above mentioned parameter by performing the following tests in the laboratory as well as in the field.

2.3.1. Laboratory test

Before conducting the performance evaluation of the planter in the field, laboratory tests were carried out for obtaining the correct seed rate.

2.3.1.1. Calibration of planter

The performance of the fabricated tractor drawn potato planter was tested in the laboratory. The calibration is done to get a predetermined seed rate of the planter. The following procedure was followed for calibration of the planter.

I. Area covered in 20 revolution of ground wheel was determined.

II. The planter was jacked up so that the ground wheel runs freely. A mark was made on the drive wheel and at some convenient place on the body of planter so as to count the revolution of the drive wheel easily.

III. The seeds were filled in the hopper and containers were placed under the furrow openers.

IV. The ground wheel was rotated manually at an average speed of tractor i.e. 1.5 km/h.

V. The quantity of seeds dropped from furrow openers for 20 revolutions were collected and weighed.

VI. Calculate the seeds dropped in kg ha^{-1}.

2.3.1.2. Mechanical seed damage test

The mechanical damage test was conducted to find out percentage of damage of seeds that takes place during actual operation. From the metered seeds the damaged seeds were weighed separately and percentage damage was calculated as follows:

$$\text{Damage percentage} = \frac{\text{Weight of damaged seed}}{\text{Total weight of seeds collected}} X\,100$$

2.3.1.3 Performance evaluation of the planter

The performance indices of a planter namely multiple index, miss index, quality of feed index and precision along with mean and standard deviation keeping theoretical spacing as base was calculated from the measured spacing between dropped seeds as follows (Kachman and Smith, 1995), (Al-Gaadi, 2011).

2.3.1.4. Mean seed spacing

Mean seed spacing (S) is the mean of total number of spacing measured.

$$S = \sum_{i=1}^{N} \frac{X_i}{N} \quad \ldots(4)$$

Where, N = total number of spacing measured, Xi = distance between consecutive seeds.

2.3.1.5. Miss index

Miss index is an indicator of how often the seed skips the desired spacing. The planter was operated in the field and the distances between two consecutive seeds were measured in a span of 50 m. It is the percentage of spacing greater than 1.5 times the theoretical spacing.

$$I_{Miss} = \frac{n_1}{N} X\,100 \quad \ldots(5)$$

Where, n_1 = Number of spacing in the region > 1.5 theoretical seed spacing, N = Total number of observations.

2.3.1.6. Multiple index

The multiple index is an indicator of more than one seed dropped within a desired spacing. It is the percentage of spacing that are less than or equal to half of the theoretical spacing in mm.

$$I_{Mult} = \frac{n_2}{N} X\, 100 \quad \ldots(6)$$

Where, n_2 = Number of spacing in the region ≤ 0.5 theoretical seed spacing, N = Total number of observations.

2.3.1.7. Quality of feed index

The quality of feed index is the measured of how often the spacing was close to the theoretical spacing. It is the percentage of spacing that are more than half but not more than 1.5 times the theoretical spacing. The quality of feed index is mathematically expressed as follows:

$$I_{qfi} = 100 - (I_{Miss} + I_{Mult}) \quad \ldots(7)$$

Where, Imiss = Miss index, Imult = Multiple index.

2.3.1.8. Precision index

Precision in spacing (Ip) is a measure of the variability (coefficient of variation) in spacing, between seeds after accounting variability due to both multiples and misses.

$$I_P = \frac{S_d}{S} X\, 100 \quad \ldots(8)$$

Where, S = Theoretical seed spacing, Sd = Standard deviation of the spacing more than half but not more than 1.5 times the set spacing S.

2.3.2. Field performance test of the planter

The developed prototype of potato planter was tested for field performance. The test was conducted at farmer's field. The test plot was prepared by local ardu plough to obtain a fine seedbed for potato planting. The TY – 254B tractor (25 hp) was used for field test. The tractor operator and three persons were employed for data collection. The following parameters were observed during the field test.

2.3.2.1. Seed spacing

During the field trial the seed to seed spacing was measured in the field at five different locations randomly with measuring tape.

2.3.2.2. Row to row spacing

While conducting the field test of the planter the spacing between two adjacent rows was measured at five randomly selected locations with the measuring steel tape and average was determined to represent row to row spacing.

2.3.2.3. Height and width of ridge

Height and width of the ridge was measured with the help of meter scale at 3 randomly selected places in each plot.

2.3.2.4. Wheel slippage

The wheel slippage of tractor was measured by marking the sides of rare tyre lugs and the distance the tractor moves forward at every 10 revolutions under no load condition and the same revolution with load on same surface was measured and expressed mathematically as:

$$\text{Wheel Slippage} = \frac{M_2 - M_1}{M_2} X\, 100 \qquad \ldots(9)$$

Where, M_2 = Distance covered at 10 revolutions of the tractor drive wheel at no load (m), M_1 = Distance covered at 10 revolution of tractor drive wheel with load (m).

2.3.2.5. Fuel consumption

The fuel consumption was determined by refill method. The fuel tank of tractor was filled up to its top, before the start of planting operation. After completing the planting operation the fuel tank was refilled up to its top by a measuring cylinder. The volume of fuel used was taken into account as fuel consumed for a particular time period.

2.3.2.6. Theoretical field capacity

Theoretical field capacity was measured by considering the width of operation and travel speed of the tractor. The theoretical field capacity was expressed in ha h^{-1} and computed by the following formula:

$$\text{Theoretical field capacity (ha / h)} = \frac{W \times S}{10} \qquad \ldots(10)$$

Where, W = Width of planter, m, S = Speed of operation, Km/h.

2.3.2.7. Effective field capacity

The effective field capacity is the actual rate of coverage including the time lost in filling the hopper and turning at the end of the rows. However in calculating the effective field capacity (ha hr^{-1}), the time consumed for effective work and the time losses for other activities such as turning, refilling of seeds were recorded.

$$\text{Effective field capacity (ha / h)} = \frac{\text{Area of Plot (ha)}}{\text{Time taken (h)}} \qquad \ldots(11)$$

2.3.2.8. Field efficiency

Field efficiency is the ratio of the effective field capacity to the theoretical field capacity as follows:

$$\text{Field efficiency} = \frac{\text{Effective field capacity}}{\text{Theoretical field capacity}} \times 100 \qquad \ldots(12)$$

2.3.2.9. Cost of Operation

The cost of operation of the potato planter in terms of Birr/ha and Birr/hr was determined considering fixed cost and variable cost with the help of straight line method. The straight line method assumes equal reduction in the value of machine every year. An economic life of 10 years and annual use of tractor and planter was considered as 850 and 300hr respectively. The detail calculation of cost of operation of planter is given in appendix table B and C.

2.3.2.10. Seed germination test in field

The planter was operated in the field and after the week of planting potato, germinated seeds were measured in a span of 5 m. The number of germinated seeds was measured in span of 5 m and the percentage of seed germinated was computed.

2.3.3. Experimental design and data analysis

Experimental treatments were set up in Randomized Complete Block Design (RCBD) with three replications used in the study. The analysis of variance (ANOVA) and mean table for different parameters were tabulated and the level of significance was reported.

3. Results and Discussion

A tractor drawn two row automatic potato planter prototype was fabricated. The performance of the machine was evaluated in the laboratory as well as in the field. The data were analyzed and results are discussed in this section.

3.1. Laboratory Performance of Potato Planter

The fabricated two row mini-tractor operated automatic potato planter was tested in the laboratory to evaluate its performance. The results are discussed in the following sections.

3.1.1. Calibration of planter

The ground wheel was rotated for 20 revolutions and metered seeds were collected from all the two furrow openers and seed rate was calculated and the results are given in table 1. The recommended potato seed rate per hectare is 2200 - 2500 kg, as per the package of practices. Hence, the developed potato planter was calibrated was achieved 2313 kg ha^{-1}.

Table 1. Calibration results planter

S. No.	Description	Value
1	Number of furrow openers	2
2	Spacing between the furrow openers, m	0.6
3	Diameter of ground wheel, m	0.6
4	Number of revolutions	20
5	Area covered in 20 revolution (m^2)	45.12
6	Potato seeds collected, kg	10.41
7	Mean seed rate (kg/ha)	2313

The effects of different speed and hoper filling level on seed rate are presented in Table 2. It was observed that the seed rate was decreased with increase in speed due to reduction in exposure time of cups to seeds. While there was an increase in seed rate with increasing hoper filling level due to opportunity of cups to pick up a seed.

Table 2. Seed rate and mechanical damage at different speed and hoper filling

Variables		Seed rate (kg/ha) (Mean)	Mechanical damage (%) (Mean)
Speed (km/h)	**Hoper filling level**		
1.5	Halve (HF1)	2344	0.82
2.0		2308	0.87
2.5		2256	0.92
1.5	Three fourth (HF2)	2349	0.83
2.0		2314	0.90
2.5		2286	0.97
1.5	Full (HF3)	2357	0.86
2.0		2320	0.95
2.5		2290	0.98

3.1.2. Mechanical seed damage

The seed were collected randomly during calibration and observed for damaged seeds from a two kg seed lot, the percentage of seed damaged were calculated. The effects of forward speed and hoper filling level on mechanical seed damage are presented in Table 2. It is clear that as the speed increase the mechanical seed damage increase in all hoper filling level of potato seeds. The mechanical seed damage was higher due to higher rotational speed of the metering roller at higher speed. At high rotational speed the cup strike the seeds with greater impact resulting in mechanical damage.

3.1.3. Performance evaluation of potato planter

The planter was tested in a ploughed field for 50 m strip length. The field testing of the planter was conducted for different combinations of forward speeds and hoper filling level. The forward speeds of 1.5 km hr^{-1}, 2 km hr^{-1} and 2.5 km hr^{-1} and hopper filling level of half, three fourth and full were selected to obtain the recommended seed spacing of 30 cm. The field performance observations on seed spacing, missing index, multiple index, Quality of feed index and Precision index were computed and presented in table 3.

Figure 1. Measurement of Seed Spacing

Table 3. Effect of forward speed and hopper filling level on performance of the planter

S. No.	Experiment runs	Mean Seed spacing, cm	Miss index, %	Multiple index, %	Quality of feed index,%	Precision index, %
1	S1HF1	31.10	12.35	11.65	76.00	14.63
2	S2HF1	33.30	18.07	10.90	71.05	17.41
3	S3HF1	36.65	21.50	10.90	67.60	18.63
4	S1HF2	30.51	15.35	11.40	73.25	15.81
5	S2HF2	33.05	15.65	12.35	72.00	16.68
6	S3HF2	36.55	22.70	11.05	66.25	19.45
7	S1HF3	30.39	12.70	14.65	72.65	16.15
8	S2HF3	33.90	16.70	10.75	72.55	16.43
9	S3HF3	37.00	21.00	9.65	69.35	18.53

3.1.3.1. Effect of forward speed and hopper filling level on mean seed spacing

The effect of forward speed and hopper filling level on seed spacing is presented in Table 3. From figure.2, it is observed that the mean spacing between consecutive seeds increased, with increasing in planter forward speed. The mean seed spacing for lowest planter forward speed (S1) was in the range of 30.39 cm to 31.10 cm and for (S2) it ranged from 33.05 to 33.90 cm. However, for (S3) it ranged from 36.55 to 37 cm for all hopper filling levels as presented in Table 3.

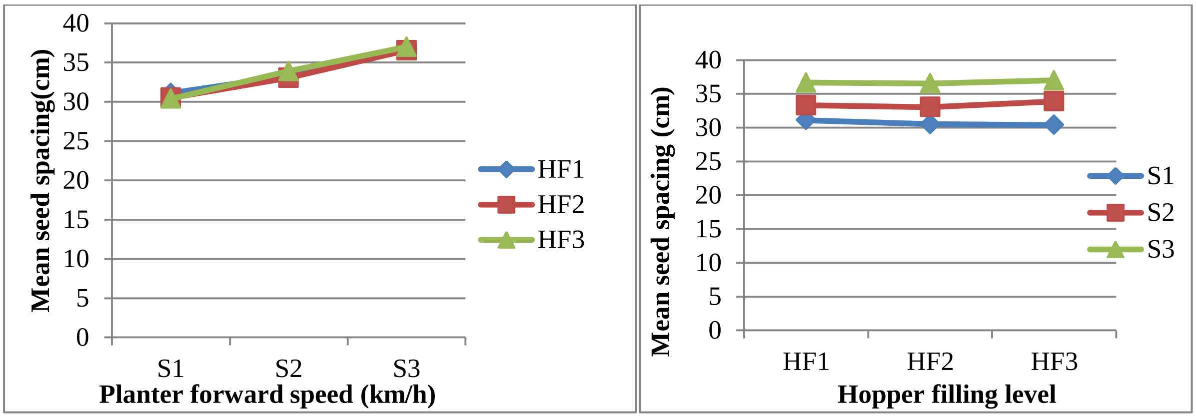

Figure 2. Effect of planter forward speed and hopper filling level on mean seed spacing

Appendix Table A1 show the results of statically analysis on the effects of forward speed and hopper fill level on mean seed spacing. Mean seed spacing was significant for various planter forward speeds ($p < 0.05$). However, mean seed spacing was not significantly affected by hopper filling level and interaction of planter forward speed and hoper filling level ($p > 0.05$). As the planter forward speed increases there was significant increase in mean seed spacing. A similar trend was observed for potato planters as reported by Gaadi and Marey (2011).

3.1.3.2. Effect of planter forward speed and hopper filling level on seed missing index

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The effect of forward speed and hopper filling level on seed missing index is given in Table 4. The missing index ranged from 12.35 % to 22.70 % for different combinations of forward speeds and hopper filling level. The highest missing index 22.70 % was observed for highest forward speed (S3) of 2.5 km/h and the lowest missing index of 12.35 % was obtained at a forward speed (S1) of 1.5 km/h. Figure 3 shows the effect of forward speed and hopper filling level on miss index. However, the effect was dominantly due to variation in forward speed than hoper filling level. Increasing in forward speed of operation from 1.5 km/h to 2.5 km/h resulted an increase in percentage of seed missing index. Momin *et al.* (2006) evaluated semi-automatic potato planter and reports that the missing index of 10 and 13% for operation speed of 1.8 and 2km/hr. Al-Gaadi (2011) also reported that the performance of an auto feed cup-belt potato planter under different operating conditions with different tuber shapes for whole and cut tubers. The highest missing index of 16.42% at 3 km h^{-1} travels speed. Appendix Table A2 show the results of statically analysis on the effects of forward speed and hopper fill level on missing index. The analysis of variance (ANOVA) showed that the planter forward speed and interaction of forward speed and hopper filling level shows significant effect ($p < 0.05$) on seed missing index.

Table 4. Effect of planter forward speed and hopper filling level on miss index (MISI)

Parameter		Source of variation			Measure of differences	
	Forward Speed level	V_1	V_2	V_3	LSD (5%)	SE(M)
		13.47^{a}	16.80^{b}	21.73^{c}	0.714	0.240
	Hoper loading level	H_{25}	H_{50}	H_{75}		
		17.30^{ab}	17.90^{a}	16.80^{b}	0.714	0.240
		Interaction(V*H)				
	Forward speed level	H_{25}	H_{50}	H_{75}		
MI (%)	V_1	12.35^{a}	15.35^{b}	12.70^{c}		
	V_2	18.05^{d}	15.65^{b}	16.70^{be}	1.237	0.416
	V_3	21.50^{f}	22.70^{f}	21.00^{g}		

Means followed by the same letter (or letters) do not have significant difference at 5% level of probability.

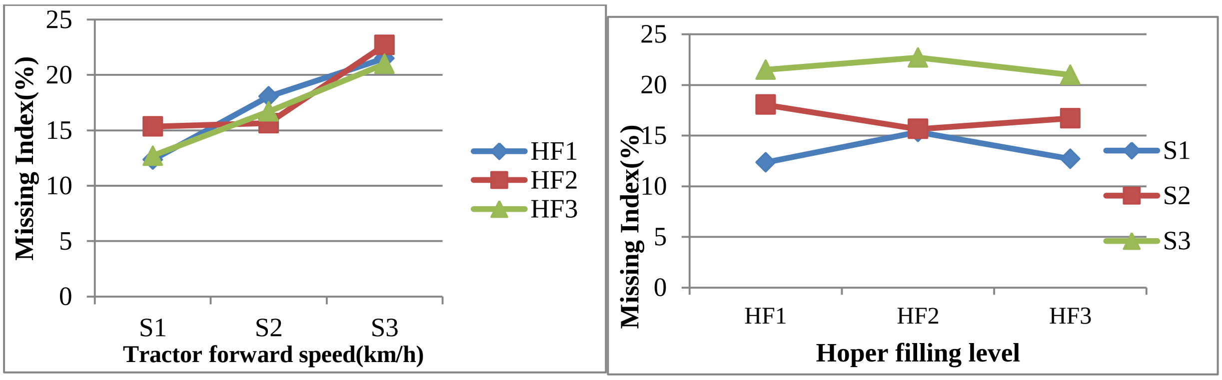

Figure 3. Effect of planter forward speed and hopper filling level on missing index

3.1.3.3. Effect of forward speed and hopper filling level on multiple index

The effect of forward speed and hopper filling level on multiple indexes is presented in Table 5. The multiple index ranged from 9.65 % to 12.35 % for all levels of forward speeds and hopper filling level. The maximum multiple index was observed, for lowest level of forward speed and medium level of hopper filling. However, the lowest multiple index, 9.65% was for maximum level of forward speed (S_3) and maximum level of hopper filling (HF_3). Fig 4 shows the effect of forward speed and hopper filling level of multiple index. The multiple index decreases as planter forward speed increases for all levels of hopper filling. Misener (1979) evaluated the cup and picked type potato planters and reports that the average multiple index per 30.5 m of row length ranged from 6.2% to 33.6% for the cup type and from 6.8%) to 29.0% for the pick type planter over various forward speeds. Appendix Table A3 show the results of statically analysis on the effects of forward speed and hopper fill level on multiple index. The analysis of variance (ANOVA) revealed that the planter forward speed and the interaction between planter forward speeds with hopper filling level ($p < 0.05$) had significant effect on the multiple indexes.

Table 5. Effect of planter forward speed and hopper filling level on multiple index (MULI)

Parameter		Source of variation			Measure of differences	
	Forward Speed level	V_1	V_2	V_3	LSD (5%)	SE(M)
		12.57^{a}	11.33^{b}	10.53^{c}	0.726	0.244
	Hoper loading level	H_{25}	H_{50}	H_{75}		
		11.15^{a}	11.60^{a}	11.68^{a}	0.726	0.244
		Interaction(V*H)				
	Forward speed level	H_{25}	H_{50}	H_{75}		
MULI (%)	V_1	11.65^{a}	11.40^{a}	14.65^{b}		
	V_2	10.90^{a}	12.35^{a}	10.75^{c}	1.257	0.416
	V_3	10.90^{a}	11.05^{ab}	9.65^{ac}		

Means followed by the same letter (or letters) do not have significant difference at 5% level of probability.

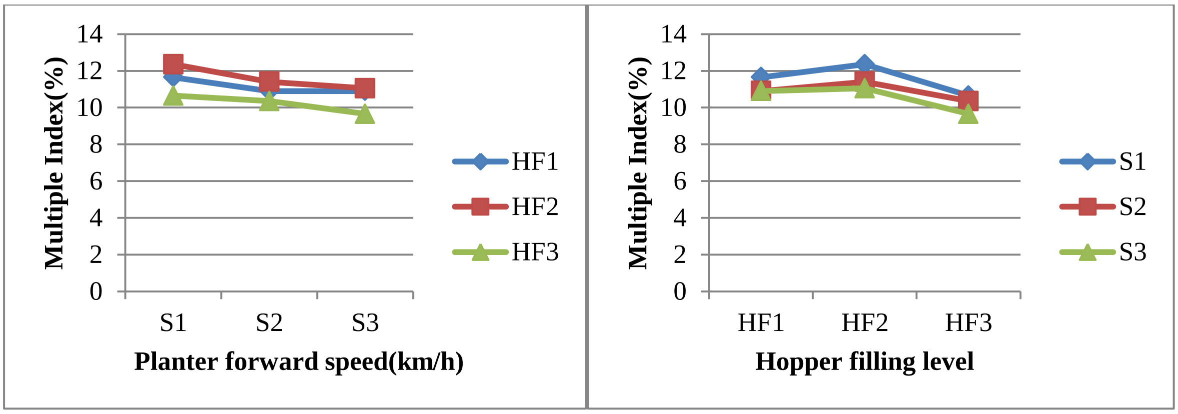

Figure 4. Effect of planter forward speed and hopper filling level on multiple index

3.1.3.4. Effect of forward speed and hopper filling level on quality of feed index

The results pertaining to quality of feed index is given in Table 6. From the table 6, it is clearly observed that, the quality of feed index ranged from 66.25 % to 76 %. The highest quality of feed index (76 %) was observed for the lowest level of planter forward speed (S1) and one fourth level of hopper filling (HF1) whereas lowest quality of feed index, 66.25 % was observed for the parameter combination of highest forward speed (S3) and half level of hopper filling (HF2). The quality of feed index decreased from 76 % to 66.25 % with increasing in forward speed as shown in Fig. 5. Similar result was observed for potato planter with high quality of feed index at lower forward speed reported by Gaadi and Marey (2011). Appendix Table A4 show the results of statically analysis on the effects of forward speed and hopper fill level on quality of feed index. The analysis of variance (ANOVA) revealed that the planter forward speed and the interaction between planter forward speed and hopper filling level had significant effect on quality of feed index at ($p < 0.05$) probability.

Table 6. Effect of planter forward speed and hopper filling level on quality of feed index (QFI)

Parameter		Source of variation			Measure of differences	
	Forward Speed level	V_1	V_2	V_3	LSD (5%)	SE(M)
QFI (%)		73.97[a]	71.87[b]	67.73[c]	0.913	0.307
	Hoper loading level	H_{25}	H_{50}	H_{75}		
		71.55[a]	70.50[b]	71.52[a]	0.913	0.307
		Interaction(V*H)				
	Forward speed level	H_{25}	H_{50}	H_{75}		
	V_3	76.00[a]	73.25[b]	72.65[b]		
	V_5	71.05[b]	72.00[b]	72.55[b]	1.581	0.532
	V_7	67.60[c]	66.25[c]	69.35[d]		

Means followed by the same letter (or letters) do not have significant difference at 5% level of probability.

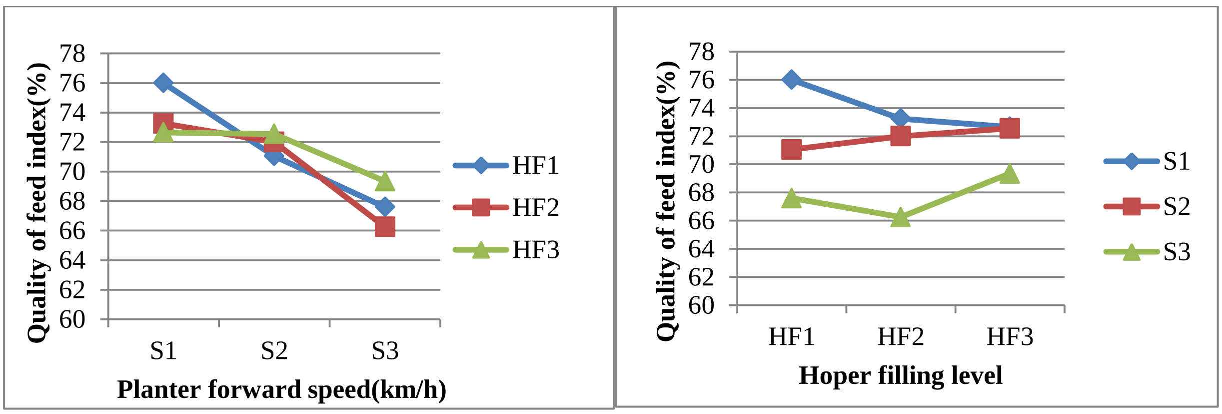

Figure 5. Effect of planter forward speed and hopper filling level on quality of feed index

3.1.3.5. Effect of forward speed and hopper filling level on precision index of

The effect of forward speed and hopper filling level on precision spacing index of planter performance is given in Table 7. The lowest precision index (14.63 %) was obtained at lower forward speed. However, the maximum precision spacing index 19.45 % was observed at highest level of forward speed. The effect of forward speed and hopper filling level on precision index is shown in Fig. 6. At the highest level of forward speed and maximum hopper filling level resulted in maximum precision spacing index. Lower values for the precision index indicate better performance compared to higher values of precision index (Kachman and Smith, 1995). Appendix Table A5 show the results of statically analysis on the effects of forward speed and hopper fill level on precision index. The analysis of variance (ANOVA) showed that forward speed of the planter on precision index was significant at probability ($p < 0.05$). However, the hopper filling level and the interaction between forward speed and hopper filling level had no significant effect on precision index at ($p > 0.05$).

Table 7. Effect of planter forward speed and hopper filling level on precision index (PI)

Parameter		Source of variation			Measure of differences	
	Forward Speed level	V_1	V_2	V_3	LSD (5%)	SE(M)
		15.53^{a}	16.84^{b}	18.87^{c}	0.587	0.198
	Hoper loading level	H_{25}	H_{50}	H_{75}		
		16.89^{a}	17.31^{a}	17.04^{a}	0.587	0.198
		Interaction(V*H)				
	Forward speed level	H_{25}	H_{50}	H_{75}		
PI (%)	V_1	14.63^{a}	15.81^{b}	16.15^{b}		
	V_2	17.41^{b}	16.68^{b}	16.43^{b}		
	V_3	18.63^{c}	19.45^{c}	18.53^{c}	1.017	0.342

Means followed by the same letter (or letters) do not have significant difference at 5% level of probability.

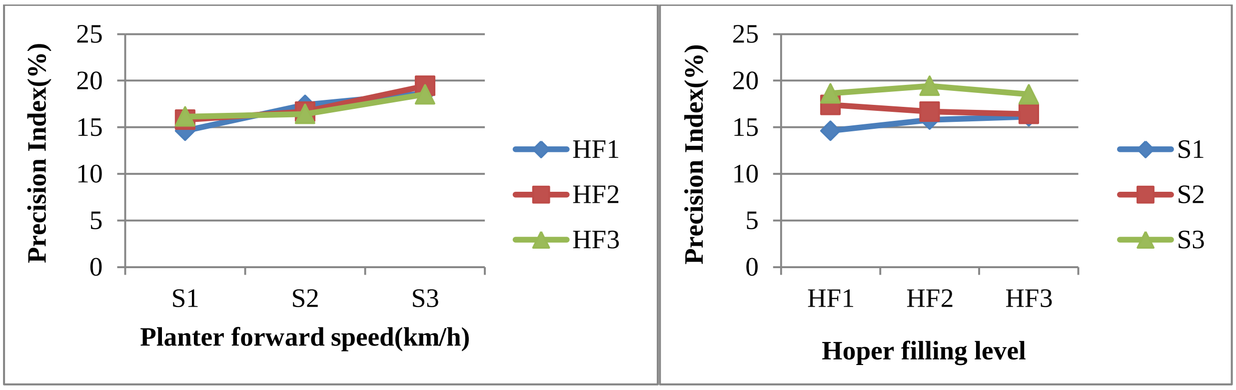

Figure 6. Effect of planter forward speed and hopper filling level on precision index

3.2. Field Performance of Potato Planter

3.2.1. Depth of seed placement

The average depth of seed was 7.04 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 depth obtained by the planter was therefore within the desirable limit.

Figure 7. Measurement of seed placement depth

3.2.2. Height and width of ridge

The measurement of height and width of the ridges made by the planter is presented in Table 8. The height of ridge was 20 to 24 cm and average distance was 21.98 cm. The bottom width of ridge was varying from 44 to 45.5 cm and average width was 44.6 cm and it did not vary between the ridges, which indicate the ridges are uniform.

Table 8. Height and Width of Ridge

S. No.	Height of Ridge (cm)	Bottom width of Ridge (cm)	Top width of Ridge (cm)
1	22	44.5	14
2	20.8	45	14.8
3	24	45.5	15.2
4	23.7	44.8	15.5
5	20	44.2	14.8
6	21.4	44	14.7
Avg.	21.98	44.6	14.83

3.2.3. Fuel consumption

The fuel consumption was measured by the procedure as described in the section 3.2.7.5. The planter was operated in an area of 0.06 ha at operation speed of 1.5 km/hr. The time and fuel consumption for the test area was measured by refilling methods. The fuel consumption obtained was 1.22 *lt/hr*. Momin *et al*. (2006) evaluated semi-automatic potato planter and reports that the fuel consumption of 1.5 lt/hr at operation speed of 1.5 km/hr.

3.2.4. Theoretical field capacity, Effective field capacity and Field efficiency

The data regarding on the theoretical field capacity, effective field capacity field efficiency are presented in Table 9. The mean theoretical field capacity, effective field capacity and efficiency of the potato planter were 0.18 ha h^{-1}, 0.15 h^{-1} and 82.13% at a forward speed of 1.5 km h^{-1}. Momin *et al*. (2006) evaluated semi-automatic potato planter and reports that the theoretical field capacity, effective field capacity and field efficiency of 0.27km/hr, 0.18ha/hr and 66.67 % respectively at operation speed of 1.5 km/hr. Asheesh M. et al., (2017) also develop and evaluated automatic potato planter and reports that the effective field capacity and field efficiency of 0.09ha/hr and 60.7 % respectively at operation speed of 2 km/hr.

Table 9. Theoretical field capacity, Effective field capacity and Field efficiency

Plot no.	Speed (km/h)	Total time required (Sec)	Theoretical field capacity (ha/h)	Effective Field Capacity (ha/h)	Field Efficiency (%)
1	1.5	213.85	0.180	0.1480	82.22
2	1.5	214.72	0.180	0.1476	82.00
3	1.5	214.12	0.180	0.1479	82.17
Avg.	1.5	214.23	0.180	0.1478	82.13

Note: - Size of plot = 20 × 4.4m and Width of Planter = 1.2 m.

3.2.5. Seed germination test in field

The mean seed germination percentage was 83.75% at a speed of 1.5 km/h. The result raveled that the developed tractor worked functionally and satisfactory.

Figure 8. Field observation seed germination

4. Summary and Conclusions

4.1. Summary

A prototype of two row automatic potato planter drawn by mini tractor was developed. The planter consists of seed metering mechanism, seed tube, furrow openers, drive wheel, power transmission and ridger. The performance of the tractor operated potato planter was tested in the laboratory and field respectively. The developed potato planter was field tested with three different forward speeds and three hopper filling level. Seed spacing indices parameters of the planter which includes, missing index, multiple index, quality of feed index and precision in seed spacing were used to evaluate functional performance of potato planter. The mean spacing index value ranged between 30.39 cm to 37 cm with increase in forward speeds. The multiple index and miss index ranged from 9.65% to 12.35% and 12.35 % to 22.70% respectively. Missing index increases with increasing planter speed and increasing seed meter velocity. Quality of feed index was ranged from 66.25% to 76% and the value of precision index was obtained in the range of 14.63 to 19.45%.

The metered seed were observed for mechanical damage which was found less than 1 % for all speeds as well as hopper filling level. The mean field test germination count of 83.75% was obtained. Average depth of potato seed placement was observed as 7.04 cm. The dimension of ridge formed during operation was as per requirement and average values of the ridge of top width 14.83cm, average height of the ridge from bottom of furrow 21.98cm and bottom width furrow 44.6 cm were recorded. The average fuel consumption (l/ha) of the planter at speed (km/h) of 1.5 were 8.1 *l* ha^{-1}. The average theoretical field capacity (ha/h), effective field capacity (ha/h) and field efficiency (%) for the speed of operation (km/h) 1.5 were 0.180 ha/h, 0.1478 ha/h and 82.13% were obtained respectively.

4.2. Conclusion

The newly developed mini tractor drawn two row automatic potato planter was evaluated in the laboratory as well as in field for its performance. Based on the results obtained the following conclusions are drawn:- The planter can be used for planting the potato Seeds in the field at required row to row and plant to plant spacing. The minimum values of missing index 12.35%, multiple indexes 10.40%, precision index 14.63% and maximum value of quality of feed index 76.00% were observed. Average seed spacing was range from 30.39 to 37.00 cm. The average mechanical seed damage (%) was varied from 0.836 to 0.956, which was less than 1 percent as per recommendation. The depth of planting 7.04 cm of potato seeds, which is within the recommended range of the average depth of potato planting was 5 cm to 10 cm. Based on the performance evaluation results, it is concluded that the tractor drawn automatic potato planter is satisfactory and can be subjected to further modifications at the seed metering mechanism so as to minimize the production cost the machine and seed damage.

Declarations

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Competing Interests Statement

The authors have declared that no competing financial, professional or personal interests exist.

Consent for publication

All the authors contributed to the manuscript and consented to the publication of this research work.

Availability of data and material

Supplementary information is available from the authors upon reasonable request.

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Appendix

Appendix A. Analysis of Variance

Appendix Table A1. Analysis of variance (Randomized Complete Block Design) of mean seed spacing

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Speed (V)	2	166.0429	83.0214	156.00	<.001
Hopper filling level (Hf)	2	0.7810	0.3905	0.73	0.494
V*Hf	4	1.5601	0.3900	0.73	0.581
Residual	18	9.5797	0.5322		
Total	26	177.9637			

Appendix Table A2. Analysis of variance (Randomized Complete Block Design) of miss index (MISI) of seed spacing's

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Speed (V)	2	311.3600	155.6800	299.38	<.001
Hopper filling level (Hf)	2	5.4600	2.7300	5.25	0.016
V*Hf	4	23.9500	5.9875	11.51	<.001
Residual	18	9.3600	0.5200		
Total	26	350.1300			

Appendix Table A3. Analysis of variance (Randomized Complete Block Design) of multiple index (MULI) of seed spacing's

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Speed (V)	2	18.8867	9.4433	17.58	<.001
Hopper filling level (Hf)	2	1.4817	0.7408	1.38	0.277
V*Hf	4	26.3733	6.5933	12.27	<.001
Residual	18	9.6700	0.5372		
Total	26	56.4117			

Appendix Table A4. Analysis of variance (Randomized Complete Block Design) of quality of feed index (QFI) of seed spacing's

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Speed (V)	2	181.0467	90.5233	106.57	<.001
Hopper filling level (Hf)	2	6.4117	3.2058	3.77	0.043
V*Hf	4	30.6833	7.6708	9.03	<.001

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Residual	18	15.2900	0.8494
Total	26	233.4317	

Appendix Table A5. Analysis of variance (Randomized Complete Block Design) of precision index (PI) of seed spacing's

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Speed (V)	2	51.0625	25.5313	72.57	<.001
Hopper filling level (Hf)	2	0.8471	0.4236	1.20	0.323
V*Hf	4	6.0621	1.5155	4.31	0.013
Residual	18	6.3328	0.3518		
Total	26	64.3046			

Appendix B

Production Costs of seed drill Prototype

Appendix Table B1. Raw material least and cost for production of the planter prototype

No.	Type of raw material	Standard size	Standard material price (Birr)	Used material size	Total price (Birr)
1	Sheet metal 1.5mm	1000x2000mm	402.30	4,000,000mm^2	804.60
2	Sheet metal 3mm	1000x2000mm	2347.82	240,000 mm^2	281.74
3	Round bar	Ø12 x 6000mm	489.99	7,250 mm	592.07
4	Round bar	Ø10x6000mm	409.99	4,060 mm	277.43
5	Flat iron	6x40x6000mm	642.50	760 mm	81.40
6	Flat iron	8x80x6000mm	815.89	1000 mm	135.98
7	Shaft	Ø30x6000mm	1,876.55	2,480 mm	775.64
8	Angle iron	4 x 40 x 6000mm	979.99	3,500mm	571.66
9	Pillow block		248.00	4pcs.	992.00
10	Metal bolt and nut	M-10x35	8.92	18pcs.	160.56
11	Metal bolt and nut	M-6x25	7.09	16pcs.	113.44
12	Rectangular pipe	30x50x6000mm	950	3,000mm	475
13	Cup		60	13Pcs.	780
14	Electrode	Ø 2.5(pack)	138.78	1pack	138.78

15	Chain	1000mm	4500	3600mm	16,200
16	Sprocket		1750	2pcs	3,500
15	Paint		200	2 gallon	400
Subtotal					**26,280.30**

Appendix Table B2. Machine and labor costs

No.	Type of machine	Machine cost/ hr	Workin g hour	Cost	Labor cost/hr	Workin g hour	Cost
1	Universal metal cutting	10.00	3	30	10.15	3	30.45
2	Welding machine	5.10	13	66.30	10.15	13	131.95
3	Power hack saw	3.67	5	18.35	10.15	5	50.75
4	Lath machine	14.94	8	119.52	20.37	8	162.96
5	Rolling machine manual	2.87	3	8.61	10.15	3	30.45
6	Radial drill machine	2.57	5	12.85	10.15	5	50.75
7	Grinding machine	0.74	3	2.22	10.15	3	30.45
8	Bending machine	2.87	3	8.61	10.15	3	30.45
Sub total				**266.46**			**518.21**

Appendix Table B3. Cost summary

Summary of cost

Raw material cost	Material wastage 2.5%of 1	Machine cost	Labor cost	Overhead cost 5% of (3 + 4)	Profit 10 % of (1+2+3+4+ 5)	Sells tax 15 % of (1+2+3+4+5 +6)	Selling price (1+2+3+4+5 +6+7)
1	**2**	**3**	**4**	**5**	**6**	**7**	
26,280.30	**657.01**	**266.46**	**518.21**	**39.23**	**2,776.12**	**4,580.60**	**35,117.93**

Appendix C

Calculation of Operational Cost by Straight-Line Method

Appendix Table C1. Assumptions operational cost calculation

Particulars	**Planter**	**Tractor (25 HP)**
Life of planter	8 years	10 years

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Salvage value	10 % on initial	10 % on initial
Annual use	300 hr	800 hr
Interest	10 %	10 %
Shelter cost	1 %	1 %
Insurance and Taxes	1 %	1 %
Repair & maintenance	10 % of initial cost	10 % of initial cost
Fuel cost		23.14 Birr./ lt (Diesel)
Labour cost	150 Birr Per day of 8 hr	301 Birr Per day of 8 hr
Purchase price	35,117.93Birr	123,000Birr

Appendix Table C2. Total operational costs

S. No.	**Particulars**	**Value**	
		Planter	**Tractor**
1	**Fixed cost**		
a	Depreciation, Birr/hr	13.17	13.84
b	Interest, Birr/hr	6.44	8.45
c	Insurance and Taxes , Birr/hr	1.17	1.54
d	Housing, Birr/hr	1.17	1.54
	Total fixed cost, Birr/hr	21.95	25.37
2	Variable cost		
a	Fuel and lubrication cost, Birr/hr		28.23
b	Repair and maintenance, Birr/hr	11.70	15.37
c	Wages, Birr/hr	18.75	37.63
	Total variable cost, Birr/hr	30.45	81.23
	Total (Fixed + variable) cost, Birr/hr	52.4	106.60
	Total planting cost, Birr/hr	**159**	