

Research Article

Development and Performance Evaluation of Animal Drawn Integrated Secondary Tillage Implement

Abdurehman Sultan*, Merga Workesa

Oromia Agricultural Research Institute, Bako Agricultural Engineering Research Center, Bako, Ethiopia

Abstract

Weed control is the most difficult task on an agricultural farm. Three methods of weed control are commonly known in agriculture. They are mechanical, chemical and biological. Mechanical weed control is easily adopted by farmers once they get convinced of its advantage. Various types of mechanical weeders have been developed. This project is involved in construction and evaluation of integrated secondary tillage implement for harrowing after discovering that tools such as, traditional plow, spike tooth harrow, hoes require high drudgery, time consuming and high labor force with poor efficiency, used for preparation of seed bed before plantation. As a solution of this problem, mechanical integrated secondary tillage implement for harrowing is developed. This implement is made by integrating cultivator and spike tooth attached back and forth on trapezoidal frame. The cultivators cut the soil and uproot the weed roots, and the spike tooth harrow, pulverizes the soil and collects the uprooted weed roots. The developed integrated harrowing implement was tested on the primarily tilled field and the relevant data were collected and statically analyzed. The field efficiency of the implement was 0.78% and has field capacity of 0.043 ha/hr. for clay soil. Thus, based on performance indicator taken to evaluate the treatments it can be concluded that the developed ISTI (integrated secondary tillage implement) has shown good result as compared to that of traditional plow.

Keywords

Weeding, Secondary Tillage, Implement, Frequency of Plow

1. Introduction

In Ethiopia cereal crop seeds are planted mostly by broadcasting method. Now a day's farmers are adapting row planting including teff crop depending upon the type of soil, topography of land and labors [5]. The relentless exploitation of agriculture and growth of population in Ethiopia have made land an extremely expensive natural resource [2]. In order to increase productivity, beyond row sowing, efforts have been made to improve the implement for better preparation of the seed bed for better germination of the crop seedling. Harrowing is one of the most important operations in crop pro-

duction system. Weed growth is a major problem for wet land crops particularly in cereal crops causing a considerably lower yield [10].

Moreover, the labor requirement for weeding depends on weed flora, weed intensity time of weeding and soil moisture at the time of weeding and efficiency of worker. Often several weeding is necessary to keep the crop weed free. Reduction in yield due to weed alone is estimated as 16-42% depending on the crop and location and involves one third of the cost of cultivation [9].

*Corresponding author: abdysultan4@gmail.com (Abdurehman Sultan)

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Most weed management in organic systems involves preventing problems by tilling weeds prior to seeding and by using best agronomic practices to give the crop a competitive edge. Once the crop has emerged, harrowing gives one more option to remove weed seedlings [4].

Weed control is the most difficult task on an agricultural farm. The weed control operations are mainly done by three methods, such as manual weeding, mechanical, and herbicide application. In our case, we apply two mechanisms which are, mechanically after primary tillage by applying integrated secondary tillage implement for harrowing before plantation and chemical herbicide application after germination take place. Weed control during the season relies mainly on time weeding with spring-tine harrows [15].

Nowadays herbicide usage is increasing. In view point of labor shortage circumstances; it is preferred as a quick and effective weed control methods without damaging the plant. But it has adverse effects on human health and environment.

Weed harrowing has been used to control weed seedlings in cereals since the beginning of the 20th century. Harrowing was recommended in the first half of the twentieth century because field experiments showed efficient weed control and increased crop yields. [6] summarized 55 Norwegian field experiments in spring cereals in 1919–1920 and reported that the weed control effect of pre-emergence weed harrowing averaged 53% and that the combined weed control effect of pre- and post-emergence harrowing averaged 81%.

The corresponding increases in grain yield averaged 16% for pre-emergence harrowing and 29% for the combination of pre- and post-emergence harrowing. Another review of old experiments showed similar grain yield responses [14].

In the old experiments, pre-emergence weed harrowing was carried out just before crop emergence and post-emergence was carried out when cereals had 2–3 leaves. The same approach is used today, but the old experiments were carried out with rigid-tine types of harrows, which were commonly used in Scandinavian up to the 1950s.

Today the agricultural sector requires non-chemical weed control that ensures food safety. Consumers demand high quality food products and pay attention to food safety. Through the technical development of mechanisms for physical weed control, it might be possible to control weeds in a way that meets consumer and environmental [8].

Mechanical weed control reduces the chemical application involved in weed control. Moreover, mechanical weeder besides killing the weeds loosens the soil. Thus, increasing air and water intake capacity, however traditional tools, implements and methods are still used by majority of the farmers for weed control. The problems usually associated with traditional methods of weeding practices are low efficiency and farmer bending over resulting in tremendous loss of energy [7].

Mechanical weed control is very effective as it reduces drudgery involved in manual weeding. It kills the weeds and also keeps the soil surface soft and loose ensuring soil aeration

and water intake capacity thereby contribute significantly to safe food production (pullen and cowell). But this method of weed control has received much less attention compared to other methods. In Ethiopia, land preparation for weed control management before plantation is performed by animal drawn traditional plow that requires higher labor input and also time-consuming process in order to control weed infestation before germination take place after seed plantation.

This study therefore, carried out performance evaluation test on a locally developed animal-drawn integrated tillage implement for harrowing, to determine its field performance as a secondary tillage implement.

2. Material and Methods

2.1. Materials

- 1) Water pipe 8- digital balance
- 2) Tines 9- sieve
- 3) Angle Iron 10- pair of oxen
- 4) Round Bar
- 5) Clamps
- 6) Square Pipe, Bolts with Nuts
- 7) Wood

2.2. Methods

2.2.1. Determination of Weight of Implement

The average weight of an ox is between 1500-3000 lb. (680.3-1360.7 kg). Well-conditioned oxen are capable of working draft loads equal to 10-12% of their body weight throughout the day and greater loads for short periods of time [13]. Weight of the developed implement is 20 kg with 70cm of working width.

2.2.2. Determination of Draft Force

The detail analysis of all the components and joint were done by taking in to consideration of the following conditions:- Pair of ox draft force (F_d) 870N, Operator force (F_o) 100-250N, The average working speed of ox is 0.63m/s [1, 11].

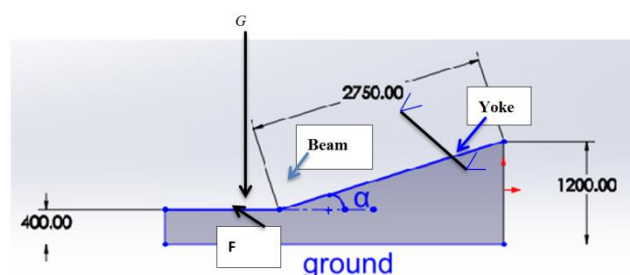


Figure 1. Layout and dimension of beam.

It's found on field observation the height of animal's and traditional plough beam length is between 1.0m to 1.4m and 2.5m to 3.0m, respectively. The average animal height of 1.2m and the average beam length of 2.75m were used for the design of implement. From (figure 1) using sine law Equation (1) the calculated angle is 17° .

$$\sin \frac{90}{2750} = \frac{\sin \alpha}{1200-400} \quad (1)$$

$$\alpha = \sin^{-1} (0.291) = 17^\circ$$

By considering α and θ are equal then F_b

$$F_d = F_b \cos \alpha \quad (2)$$

Where, α = angle of the beam from the horizontal. F_b =force of beam.

$$F_d = F_b \cos \alpha$$

$$F_b = F_d / \cos \alpha$$

$$F_b = 870 / \cos 17^\circ$$

$$F_b = 910\text{N}$$

Hitch is a part which connects the beam and the implement. F_h =force of hitch.

$$\sum F_y = F_b \sin \alpha = 0 \quad (3)$$

$$\sum F_z = F_b \cos \alpha - F_h = 0 \quad (4)$$

$$F_h = F_b \cos \alpha = 910\text{N} \cos 17^\circ = 870\text{N}$$

$$F_h = 870\text{N}$$

$G = W \cdot mg$, where: $-G$, gravitational force, W , weight of implement, mg , acceleration due to gravity.

Where, G is gravitational force of the implement (excluding weights of the yoke and 1/3 weights of the beam) F , is tangential interfacial force of the share from the free body diagram (Figure 1), is calculated by taking mass of implement 20 kg and gravitational force of the implement 196.2N. Average force of operator 175N.

2.2.3. Description of the Developed ISTI Implement

After discovering that tools such as, traditional plow, spike tooth harrow, hoes require high drudgery, time consuming and high labor force with poor efficiency, used for preparation of seed bed before plantation and determining draft force and force on beam, mechanical integrated secondary tillage implement for harrowing is developed.

The developed secondary tillage implement is animal-drawn and pulled with pair of oxen or single equine animal (horse, mule, donkey) by means of beam lock ring which is made on the main frame made of angle iron in trapezoidal shape (Figure 2). This implement is made by integrating cultivator and spike tooth attached back and forth on trapezoidal frame.

1. The cultivator with adjustable (10-15cm depth) straight shank mounted alternately with clamp and bolt on the square bar which cut the soil and uproots the weeds and hidden de-

cayed weed roots.

2. The second part is spike tooth fixed on the rear frame that collects the uprooted weeds with a working width (50-70cm) and pulverizes the soil for better air and water circulation.

Its main feature includes: beam lock pin, beam level controller, main angle iron frame, square pipe bar, handle, fixing pipe, spike tooth, share attached to shank.

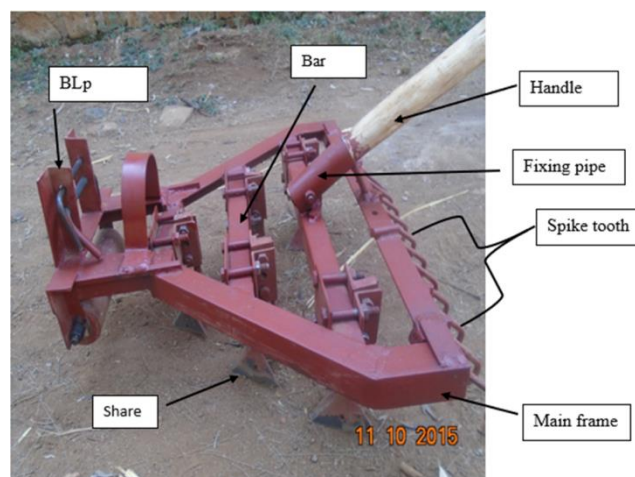


Figure 2. Developed integrated secondary tillage implements for harrowing.

2.2.4. Test Conditions

Performance of the machine (integrated secondary tillage implements) varies with the condition of the field soil type, Topography and operator.

2.2.5. Soil Physical Properties of Study Area

Table 1. Result of the soil in the study area.

No	Soil type	Bulk density (g/cm ³)	SMC %
1	Clay	0.8	24

2.2.6. Experimental Field

The field tests were conducted during the 2020 and 2021 cropping season on purposely selected FTC's (farm training centers) of East wollega zone of oromia region.

The ISTI (integrated secondary tillage implement) had been evaluated on clay soil sown by traditional plow in the primary tillage and pair of oxen used for the test. The factor was frequency of plow.

The treatments plowing 2* with developed ISTI, plowing 3* with developed ISTI and traditional plow for both kuncho and filagot variety. The test plot was 20m X 30m, three replications for each treatment. The final operation for all treatments was done on the planting day.



Figure 3. Harrowing operation.



Figure 4. Weed counting and germination.

2.2.7. Performance Indicator Parameters

The parameters Field capacity, field efficiency yield and weed number were taken as performance indicator. The machine evaluated in terms of its field efficiency and effective field capacity.

Effective field capacity (FCE) is the average output per hour, calculated from the total area operated in hectares and the total work time.

$$Ce = S \cdot W \cdot Fe / 10 \quad [16]$$

Theoretical field capacity (FCT) is calculated from the mean values of working width and working speed, as follows: FC working width * working speed.

$$TFC = W \cdot S$$

Field efficiency (FE) gives an indication of the time lost in the field and the failure to use the full working width of the implement.

It is calculated as follows: $FE (\%) = FCE / FCT \cdot 100$ [16].

Where: -Ce=effective field capacity, S=the travel speed of

the cultivator, W=working width, Fe=field efficiency,

Yield: is amount of grain in weight.

No of weed: is the amount of *number weed* counted per square sample box.

This weed can be: -

- 1) newly germinated and
- 2) rehabilitated (regerminated).

2.2.8. Experimental Design

The experiment was done in descriptive static. With three replications.

2.2.9. Data Analysis

All the data collected were analyzed using R software version 4.1.0. The treatments were compared for their significance using calculated least significance difference values at 5% level of probability.

3. Result and Discussion

The result of field performance indicated on the following tables, the variety is taken to see the yield difference b/n the factors (FOP, TP as a control) and not as a factor.

Table 2. For Filagot variety.

No.	Parameters/treatment	Ger.(no/sb)	Reh. (no/sb)	FC (ha/hr.)	FE %	TFC (ha/hr.)	YIELD (Q/ha)
1	Fil.Fop 3*	45 ^b	5.6 ^a	0.043 ^a	0.78 ^a	0.55 ^a	13.766 ^a
2	Fil.Fop 2*	70.6 ^b	2.3 ^{bc}	0.036 ^b	0.73 ^b	0.49 ^b	11.566 ^a
3	Fil.Tp	125 ^a	0.6 ^c	0.024 ^c	0.66 ^c	0.366 ^c	3.50 ^b

Key: FOP, frequency of plow, TP, traditional plow, Ger. germinated weed, Reh. Rehabilitated weed sb: sample box

Table 3. For kuncho variety.

1	Kun.Fop 3	34.3 ^b	4.6 ^{ab}	0.043 ^a	0.78 ^a	0.55 ^a	13.933 ^a
2	Kun.Fop 2	65 ^b	1.3 ^c	0.036 ^b	0.73 ^b	0.49 ^b	10.133 ^a
3	Kun.Tp	122 ^a	0.3 ^c	0.024 ^c	0.66 ^c	0.366 ^c	12.563 ^a

Key: FOP, frequency of plow, TP, traditional plow, Ger. germinated weed, Reh. Rehabilitated sb: sample box
Weed means followed by the same letter (letters) do not have significant difference at 5% level of probability.

Table 4. Over all result of developed implement.

No.	Parameter/result	Ger. (no/sb)	Reh. (no/sb)	FC (ha/hr.)	FE %	TFC (ha/hr.)	YIELD (q/ha)
1	Mean	76.6	2.5	0.034	0.72	0.046	10.9
2	CV%	33.7	53.1	6.04	2.1	4.9	20.3
3	LSD	47.1	2.4	0.0037	0.027	0.0043	40.27

LSD: least significant difference, CV: coefficient of variations, sb: sample box

Field capacity: is the amount of work performed in ha/hr. as indicated the Table 1, 0.043ha, 0.036ha and 0.024ha were covered by hour respectively for the treatments, the FOP*3, FOP*2 and TP, FOP *3 is high ranked this is due to width of operation as compared to TP and speed increment due to pulverization of the soil when compared to FOP*2. Statistically there is significance difference among treatments at 5% level of probability.

Field efficiency: is indication of time lost in the field. 0.78, 0.73 and 0.66 were the result found on the field. There is significant difference among the treatments at 5% level of probability. The developed ISTI with 3* FOP shows better result when the FOP Increases this is due to the very fact that pulverization of the soil is high when frequency of plow increase.

Grain yield: in terms of grain yield performance the developed ISTI with 3* FOP gave comparable and showed better result than that of traditional plow this is due to fineness of soil and weed infestation is high in traditional plow. The effects of use of the modified plough and tillage frequency on grain yield [3]. Reduction in yield due to weed alone is estimated as 16-42% depending on the crop and location and involves one third of the cost of cultivation [10].

Weed Index

Weed index is the measure of the efficiency of a particular treatment when compared with a weed free treatment. It is expressed as percentage of yield potential under weed free. More conveniently weed index is the percent yield loss caused due to weeds as compared to weed free check. Higher weed index means greater loss [12].

The graph below shows the difference of result in number of weed (germinated, rehabilitated and total) and yield along variety with the same level of frequency of plow.

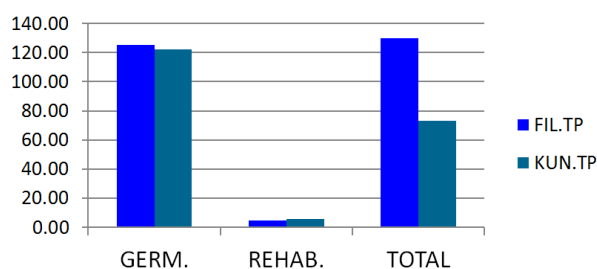


Figure 5. Effect of traditional plow on the variety.

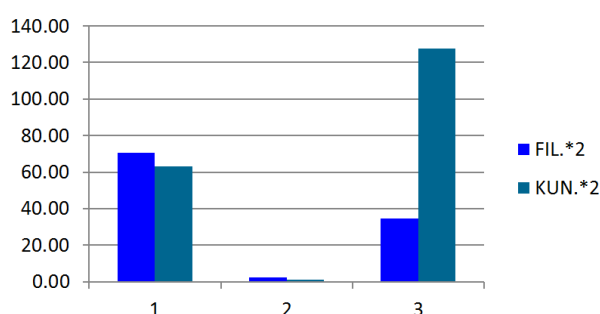


Figure 6. Effect of developed ISTI with 2* FOP on variety.

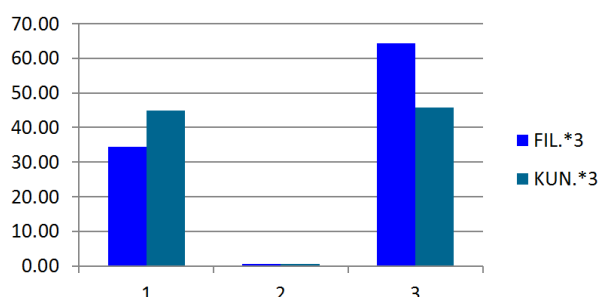


Figure 7. Effect of developed ISTI with 3* FOP on variety.

4. Conclusion and Recommendation

Based on performance indicator taken to evaluate the field capacity and of developed ISTI is 0.043ha, as compared to 0.024ha, of traditional plow, the field efficiency of the developed ISTI is 0.78, and 0.66 is for traditional plow. The destruction index developed ISTI shows better in number of weeds per sample box is high in average 123.5 for traditional plow and 40 for developed ISTI. So, it can be concluded that the developed ISTI has shown good result as compared to that of traditional plow in terms of minimizing: -

- 1) number of weed germinated
- 2) rehabilitated
- 3) Field capacity

4) Field efficiency as well as yield in Q/ha

Therefore, it can be recommended for popularization for any row planted crops especially teff and wheat as it gives better field capacity, field efficiency and other parameters taken.

From the field experiment the frequency of plow has effect on the yield so increasing the frequency of plow will lead to better yield production.

It's better to use the developed implement than traditional plow to get high yield increment. Beside this it's recommended that the project (paper) will help for next research work in order to develop the mechanical weed destruction to high level.

Abbreviations

ISTI	Integrated Secondary Tillage Implement
FOP	Frequency of Plow
TP	Traditional Plow

Conflicts of Interest

The authors declare no conflicts of interest.

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