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RESEARCH ARTICLE

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DEVELOPMENT OF ANIMAL DRAWN MULTICROP PLANTER

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ABSTRACT

This study was undertaken to design, fabricate and evaluate the performance of a prototype planter capable of planting different seeds at predetermined seed spacing's and planting depths. The planter, consisting of a frame, seed hopper, seed metering devices, seed tube/spout, adjustable furrow opener, adjustable furrow covering device, and drive wheels. A grooved disc roller type seed metering device was used. The power transmission from the ground wheel was employed to operate and control the seed-metering device. The test results indicate good performance for maize, haricot bean and sorghum. The effects of three main factors, three different types of seed, three levels of planter forward speeds, three levels of hopper filling were investigated in a split- split plot design with 3 x 3 x 3 factorial experiment on performance of the metering mechanism to establish the average percent of seed spacing indices distribution by the planter. The pattern of distribution of the seed in the row and the percentage of seed spacing indices were examined. The treatments that were examined consisted of three types of seeds, three levels of planter forward speeds and three levels of hopper filling. The results indicate that the effects of planter forward speeds on seed spacing indices were statistically significant ($p < 0.05$).The mean field capacity, field efficiency, depth were 0.12 ha/hr (8.33 hr/ha), 71% and 4.94cm with coefficient of variation of 0.042 (4.20%), respectively. The planter established acceptable plant population; 7.33, 11 and 15.33 plants within rows of 2 m length for maize, haricot beans, and sorghum, respectively, when compared with design or desired number of 8, 12 and 14 plants with maize, haricot beans and sorghum, respectively. Based on the performance evaluation results, it is concluded that the prototype planter can be efficiently, effectively and economically used by the majority of farmers

Key words: development, planter, index

1. INTRODUCTION

Agricultural mechanization is the use of mechanical devices or systems to replace human muscle in all forms and at any level of sophistication in agricultural production, processing storage and so on in order to reduce tedium and drudgery, improve timeliness and efficiency of various farm operations, bring more land under cultivation, preserve the quality of agricultural produce, provide better rural living condition and markedly advance the economic growth of the rural sector [11].

About 69% of the Ethiopian farmers have farmlands less than or equal to one hectare in size and average grain yield for various crop is less than one metric ton per hectare [3]. It is very difficult for these farmers to own and operate costly agricultural machinery and equipments that can establish the optimum plant population. Hence, in most part of the country, manual broadcasting method of sowing is still in use. This method of crop establishment adversely affects the seed requirement and production per unit area. The broadcasting method of crop establishment results in improper placement of seed, fails to put the seeds firmly in the soil, leads to uneven placement of seeds at correct interval and exposes seed for consumption by rodents and birds.

As our population continues to increase, it is necessary that we must produce more food within smaller land, but this can only be achieved through some level of mechanization. However, planting machine or planter that is normally required to produce more food is beyond the buying capacity of small holder farmers. These small holder farmers still continue to plant manually, the result of which is low productivity especially in the production of grains. It is therefore necessary to develop a low cost planter that will reduce tedium and drudgery and enable small holder farmer to produce more foods.

Thus, it is important to improve the planting operation by reducing human effort, and increasing stand accuracy and field capacity. Furthermore, developing agricultural sector requires modern techniques and suitable agricultural mechanization which will increase the agricultural production and reduce the level of manual labour, which represents 85% of the total labor force, involved in agricultural sector [3]. Nonetheless, Ethiopia as a nation and the Ethiopian farmers, as the major section of the population, lacks the means to establish optimum plant population of almost all crops timely.

The objective of this study therefore was to develop a low-cost animal drawn two-row seed planter for smallholder farmers.

2. MATERIALS AND METHODS

2.1. Description of the planter

The row planter (figure1) was developed at Asella Agricultural Mechanization Research center, Asella Ethiopia. The planter consisted of frame, seed hoppers, metering mechanisms, furrow openers, furrow covering devices and drive wheels.

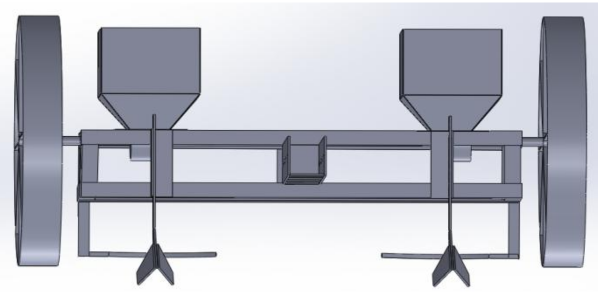

Figure 1. Front view of the prototype planting machine

(a) **Main frame: -** The frame is the skeleton of the planter supports all other component parts of the planter. Mild steel angle bar of 30 mm x 30 mm and 3 mm was used to give the required strength and rigidity, so that it can withstand all types of load during operation. The frame was provided with holes on both ends for shaft bearings and supports of drive/ground wheels that power to operate the metering devices.

(b) **Hopper: -** The hopper is made of mild steel sheet metal having a shape of inverted frustum of square pyramid truncated square bottom and top. It has two compartments; one for seeds and the other one for granular fertilizer. The total capacity of the hoper is 6710 cm^3.

(c) **Metering roller disc: -** The metering disc roller is made of 78 x 90 mm (length x diameter) aluminum alloy roller with cells on the periphery. The size and number of cells on the roller depended on the size and shape of seeds and desired rate of planting for the particular crop under consideration, respectively. The cells, on circumference of the aluminum alloy roller, were spaced to give plant spacing of 25, 18 and 15 cm when planting maize, haricot bean and sorghum, respectively. The metering rollers with cells drilled on their circumferences in two rows, one row for seed and the other for fertilizer, were mounted and locked in place on the driving shaft.

(d) **Adjustable furrow opener: -** Adjustable furrow openers provided V-shaped/winged ground engager were designed to avoid seed rebounding and to improve seed placement accuracy. The shanks/standards of the furrow openers were fabricated from 40 mm x 5 mm mild steel flat bar while the shovel was made from 4 mm thick mild steel sheet metal. The wings of the furrow openers were beveled and had a rake angle of 45^o with the horizontal. The wings were welded to the steel shank that was hitched to frame of the planter with bolts and nuts.

(e) **Adjustable furrow covering: -** The drag bar type adjustable furrow covering devices wasmade of 30 mm x 3 mm mild steel flat bar and mild steel angle bar of 30 mm x 30 mm and 3mm.

(f) **Drive wheel design: -** The drive wheels were made of mild steel and are integral parts of the seed metering mechanism connected to the seed metering device directly. The wheel had eight spokes made from mild steel rods and were welded to the rim and hub at the center of the wheel that serves as bushing or shaft bearing, at equal interval.

(g) **Seed tube:-**The seed tube/ discharge spout had a trapezoidal shape and connected to a short pipe through which the seeds is guided into the furrow bottom and deposited. The material used to construct the trapezoidal discharge spouts was mild steel sheet metal with thickness of 1.50 mm.

2.2. Performance Test and Evaluation

Two sets of tests were performed; laboratory investigation to calibrate the machine in terms of seed rate, seed damage, and seed spacing, and field tests carried out to obtain actual overall performance of the machine. The seed variety used for the testing maize (Melkassa-2), haricot bean (Awash-1)and sorghum (Gubiye) seeds were obtained from Ethiopian Seed Enterprise, Asella Branch.

2.2.1 Seed damage test

The test for percentage seed damaged was done with the machine held in a similar position to that described above, with 2.5 kg of seeds loaded into each of the hoppers. A paint mark was made on the drive wheel to act as a reference point to count the number of revolutions when turned, and a polythene bag was placed on the discharge spout to collect the seeds discharged. The wheel was rotated 20 times in turns and the time taken to complete the revolution was recorded with the aid of stop watch. The seeds discharged from the spout were observed for any external damage. Germination tests were also conducted to assess the level of internal damage by the metering mechanism.

2.2.2. Evaluation of Seed spacing/distribution

To assess uniformity of seed placement and seed spacing distribution, the planter was pulled by 15 hp mini tractor at predetermined forward speed and hopper loading capacity on manually dug, leveled, fine sand applied, gently packed and watered soil surface. At the end of each test run, measurement of successive seed spacing was taken to calculate the mean seed spacing, seed miss index, seed multiple index, quality of feed index and precision in spacing were estimated based on the following equations [7].

$$MISI(\%) = \frac{n_{III} + n_{IV} + n_{V}}{N} \times 100 \qquad 1$$

$$MULI(\%) = \frac{n_{I}}{N} \times 100 \qquad 2$$

$$QTFI(\%) = \frac{n_{II}}{N} \times 100 \qquad 3$$

$$PREC(\%) = \frac{S_{II}}{X_{ref}} \times 100 \qquad 4$$

Where: MISI = miss index

MILI = multiple index

QTFI = quality of feed index

PREC = precision index

x_{ref} = theoretical (desired) seed spacing

n_I = number of seed spacing's less than or equal to half of the desired spacing (< 0.5 x_{ref}).

n_{II} = number of seed spacing's close to the theoretical seed spacing (0.5 to 1.5$x_{ref,}$).

n_{III} = number of seed spacing's greater than 1.5 times the theoretical seed spacing (>1.5 $x_{ref,}$).

2.2.3. Field Test

A plot of 180m^2area was marked out on the field. The plot was prepared under a conventional tillage system to obtain a fairly flat field. Field tests were conducted to determine the effective field capacity and efficiency and average depth of placement of seeds. Investigation into the field efficiency and effective field capacity of the planter involved continuous observation and timing of each activity involved in the planting operation. Two stop watches were used to estimate activity time, while four people were involved in the determination of field efficiency. One stop watch was used to record the time losses such as those for turning at field ends, removal of clogs, and adjustment. The other stop watch was used to continuously measure the time during which the planter actually performed the intended operation i.e. time for actual planting operation. Field efficiency and effective field capacity was determined using the following relationship [9].

$$V = \frac{D}{t_a} \quad 5$$

Where: - V = Working speed,

D = distance of run (m)

t_a = average time of each pass (second)

$$e = 100 \times \frac{T_e}{T_t} \quad 6$$

Where: - e = field efficiency (%).

T_e= effective operating time (sec.)

T_t=totaltime= (effective operating time + time lost for turning)

$$C_e = \frac{W_e \times S_{mf} \times e}{10} \quad 7$$

Where: - Ce = effective field capacity (ha/hr)

W_e = implement effective width/inter row spacing (m)

S_{mf} = mean forward speed (km/h)

e = field efficiency (decimal)

3. RESULTS AND DISCUSSIONS

3.1. Seed damage test

The numbers of mechanically damaged, i.e. bruised, skin removed or crushed seeds were counted and their percentage was computed. The mean percent seed damaged for maize, haricot bean and sorghum seeds were found to be 1.51±0.52%, 1.28±0.34% and 1.95±0.40%, respectively. Seed damage increased with increasing metering roller speed and this was attributed to shearing and jumping of seeds against the wall of the hopper at high speeds and the magnitude of damage was depended on the strength of the seeds.

The results of germination test revealed that mean percentage germination of 97.38±0.44, 83.61±0.37 and 80.46±1.36 for maize, haricot bean, and sorghum, respectively. A difference between the percentage germination rate before and after metering the seeds can be related to the metering rollers quality, the variability of the seeds and the friction between the metering device and seeds. The reduction in percent germination in maize, haricot beans and sorghum were 0.68, 1.39 and 0.54%, respectively, indicating that the mechanical damages caused by the metering devices on the respective seeds were within acceptable level, less than one percent, except that of haricot beans which was 1.39 % indicating the need for improvement of the metering device to safely handle haricot bean seeds.

3.2. Seed spacing distributions

Performance indicators such as spacing indexes that include miss index (MISI), multiple index (MULI), quality of feed index (QTFI) and precision (PREC) were used to assesses functional fulfillment of the prototype planter.

3.2.1. The seed miss index

Experimental results show that operational speed had significant effect on percent miss index. However, the level of effect varied with crop type. Increasing speed of operation from 3 km/hr to 7 km/hr had increased the percent miss index when planting maize, while the effect of speed increase from 3 km/hr to 5 km/hr when planting haricot beans and sorghum did not have significant effect on percent miss index. In general, increase in operational speed tended to increase percent miss index when planting maize, haricot bean, and sorghum seed using the prototype planter.As figure 2 clearly indicated forward speed greater than 5 km/hr would result in percent miss index of approximately equal to ten and above which exceeds the acceptable level of percent seed miss index.

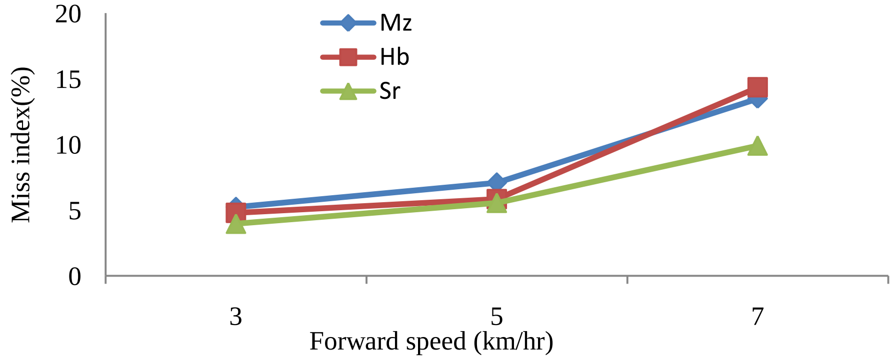

Figure 2.Effects of planter forward speeds on seeds miss index.

3.2.2. The seed multiple index

Planter forward speed, level of hopper fill and the combined effect of the two had no significant effect on mean percent multiple indexes of maize and sorghum, but the effect on mean percent multiple index was significant difference for haricot bean between speeds of 3 and 5 km/hr and that of 7 km/hr. The combined effect of level of hopper filling and forward speed on percent seed multiple indexwas also had significant effect (P < 0.05) for all seeds at forward speed of 7 km/hr. The highest percent seed multiple index occurred at planter forward speed of 5 km/hr for maize, haricot bean and sorghum. The lowest values, of the same, were recorded at planter forward speed of 7 km/h.

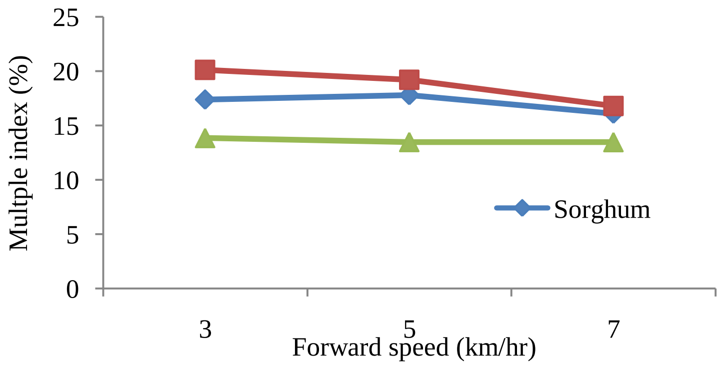

Figure 3. Effects of planter forward speeds on seeds multiple indices

3.2.3. The quality of seed feed index

Forward operational speed of the planter and seed types had significant (P < 0.05) effect on the quality of seed feed index (percent cell fill) at speed of 7 km/hr regardless of the type of seeds used. The effect of percent or level of seed fill in the hopper was not statistically significant (P >0.05) on the quality of seed feed index. This clearly indicated that the forward speed of the planter, i.e. the speed of the metering mechanism, had detrimental effect on the percent quality of seed feed index (percent cell fill).

As we can see from figure 4, the highest percentquality of seed feed indexes of 80.91, 75.09, and 78.65% were observed with maize, haricot beans and sorghum, respectively, when the planter was operated at the forward speed of 3 km/hr. The lowest percent quality of seed feed index of 73.01, 68.86 and 73.00 were observed with maize, haricot beans and sorghum, respectively; when the planter was operated at linear speed of 7 km/hr. From these, it could be concluded that operating the planter at speeds greater than 5 km/hr would reduce the plant population/ ha, hence could lead to reduced harvest at the end of the day.

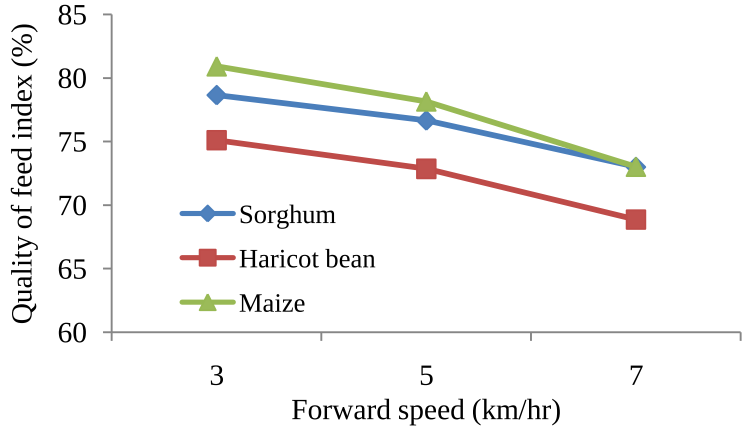

Figure 4. Effects of planter forward speeds on quality of seed feed indexes.

3.2.4. The seed precision index

Analysis of the effect of operational speed of the planter, hopper fill level and seed types on percent seed precision index (percent spacing variation) indicated that only planter forward speed had significant ($P < 0.05$) effect on the percent seed precision index; means that variation, in seed spacing within a row, increases as planter linear forward speed increases, i.e. as the speed of operation is increased, one should expect high variability in seed spacing, which is not a desired trait. Nonetheless, level of seed in the hopper did not have significant ($P > 0.05$) effect on the percent seed precision index. The combined effect of seed level in the hopper and forward speed of the planter, on the percent of seed precision index, was significantly difference ($P < 0.05$) at the planter forward speed of 7 km/hr only. Figure 5, clearly indicated that planter linear forward speeds greater than 5 km/hr would result in seed spacing variations of over 13%, though the variations for maize and sorghum were greater than 15 and 17%, respectively at plant speed of 5 km/hr.

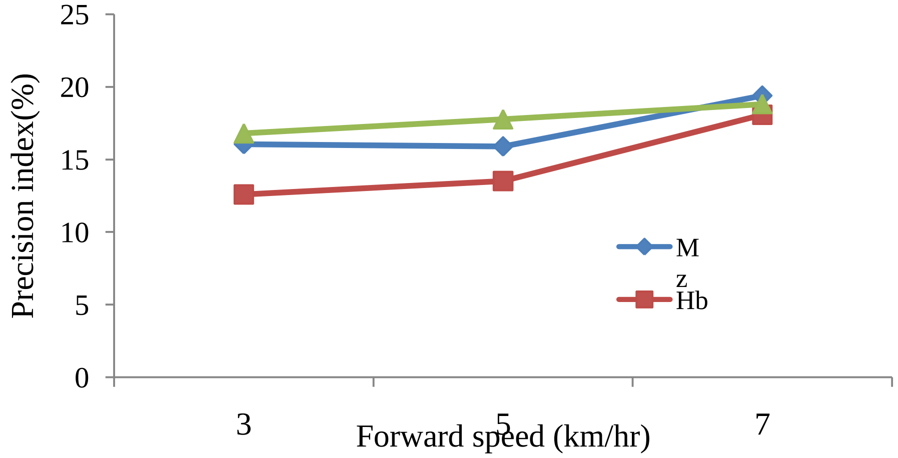

Figure 5. Effects of planter forward speeds on percent seed precision index.

4.2. Field efficiency and field capacity of the planter

The mean field capacity and efficiency of the prototype planter were 0.12 ha/hr (8.33 hr/ha) and 70.57%, respectively. This shows that the prototype planter can plant a hectare of land in slightly over eight working hours. In another words, the planter can best suit majority of the Ethiopian farmers. The field efficiency of the prototype planter agreed, as recommended [8], for planters, is within the acceptable level.

5.2. Conclusion

From the forgoing summary, one can see that the performance of the prototype planter in terms of percent seed miss index (MISI, % seed skip), percent seed multiple index (MULI, % redundancy), percent quality seed feed index (QTFI, % cell fill), percent seed precision index (PREC, percent spacing viability), depth of planting, plant count/stand (achievement of the optimum plant population), field capacity, field efficiency, labour cost and economics of owning and operating the machine is acceptable. Above all, the prototype planter successfully handled seeds of three different crops, maize, haricot beans and sorghum seeds. Hence, it can be concluded that the prototype planter can be efficiently, effectively and economically used by the majority of Ethiopian farmers. However, the speed of the planter should not exceed 5 km/hr in order not to seriously and negatively affect the percent cell fill or the recommended plant population.

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