Development of a Four-Row Tractor Mounted Soybean Planter

Hammanadama Faruk Abubakar[1], Maiwada Liman Suleiman[2], Aminu Saleh[3]
[1]*Adamawa State Polytechnic, Yola, Nigeria*
[2,3]*Ahmadu Bello University, Zaria, Nigeria*

Abstract: **The traditional method of planting soybean in Nigeria does not result in obtaining maximum yield of the crop per hectare. This is due to either incorrect number of plants per stand, incorrect plant to plant spacing or incorrect row to row spacing. This research work was embarked upon to develop a Four-Row Tractor Mounted Soybean Planter. The planter was designed, fabricated and evaluated in Agricultural and Bio-Resources Engineering Department, Ahmadu Bello University, Zaria, during 2021 raining session. The planter has the functional units of four hoppers, four seed metering units, four delivery chutes, four furrow openers, and four soil covering devices. The developed planter was evaluated in both laboratory and in the field in terms of planting speed, seedling emergence, plant-to-plant spacing, seed delivery rate, number of seeds per hole and percent seed damage. The laboratory test of the planter shows that it delivered one (1) single seed per hole of TGX 1951-3F variety of soybeans and two (2) seeds per hole of TGX1448-2F varieties of soybeans respectively. The plant to plant spacing average was 5.7 cm within row, and 50 between rows. The results obtained also showed that the seed delivery rate was 48.2kg/ha, field efficiency of 75.5%, effective field capacity of 0.792 ha/ha while the tractor was powered with 50 hp tractor (EICHER 5660). We conclude that the planter was able to satisfy the agronomic requirements for soybean planting, and thus will relieve medium scale farmers of the rigors involved in soybean planting.**

***Keywords*: Development, planter, tractor mounted, furrow opener,**

I. INTRODUCTION

Soybean (*Glycine max* L.) belongs to the family *Fabaceae* a sub-family *Faboideae*. It is one of the major oil seed crops of the world. Among the leguminous crops soybean contains high amount of protein (40%) and oil (20%) and a good amount of other nutrients like calcium, phosphorus, iron and vitamins (Wahab *etal.*,2002). Generally human consumes protein from plant and animal's source. The low-income people in Nigeria, especially those living in the rural areas, cannot afford for animal protein such as egg, milk, meat and fish in their daily diets because of their exorbitant costs (Wahab *et.al*., 2002). Therefore, soybean plays a vital role to supplement protein in our food.

The rapid growth in the poultry sector in the past few years has also increased demand for soybean meal in Nigeria. It is believed that soybean production will increase as more farmers become aware of the potential of the crop, not only for cash and food but also for soil fertility improvement as they fix atmospheric nitrogen and thus reduce fertilizer used by farmers (Dugje *et al.*, 2009).

In 2020, the production of soybean meal in Nigeria was estimated to be 368 thousand metric tons. Between 2010 and 2020, the soybean meal in the country steadily increased, registering the highest growth in 2011, when the production grew by about 25% compared to the previous year. In the last year, the production remained stable and registered a growth against 2019, (Simona Varrella, 2020). Based on the increasing production of soybean in Nigeria there is a need for the production of a precision soybean tractor mounted planter that can complement this effort to make more production.

Manual method of soybean planting results in shallow seed placement, difference in plant spacing and fatigue on the farmer which limits the size of the field planted

The traditional method of planting soybean result in obtaining either incorrect number of plants per stand, incorrect plant to plant spacing or incorrect row to row spacing. Therefore, appropriate soybean planter that will reduce drudgery and enable small-holder-farmers to produce more soybean in an environmentally friendly condition needs to be developed (Bamgboye and Mofolasayo, 2006). In view of this, tractor mounted soybean planter when develop would go a long way in overcoming the challenges encountered in soybean production. The aim of this research work, therefore, is to developed and evaluate four-row tractor mounted soybean planter suitable for planting commonly grown soybean varieties in Northern Nigeria

II. MATERIALS AND METHODS

The materials used in developing the planter include: angle iron of 60 mm x 60 mm of mild steel, 2 mm mild steel sheet metal, 5 mm x 50 mm flat bar, 25 mm diameter mild steel bar, 25 mm diameter bearing, 15 mm x 196 mm aluminum disc, 17 and 22 bolts and nuts.

Description of the planter

The planter comprised of the following components: the hopper, frame, metering mechanism, furrow opener, delivery tube, furrow cover, and traction/press wheel. The detailed description of these components of the planter are (Figure 1 show the picture of the planter):

Hopper

The hopper was made from a mild steel metal plate of gauge 16 (2 mm) forming a trapezoidal on the inside and constructed to have an external cuboidal shape with a top area of 400 mmx 150 mm, and the height is 400 mm. it was designed with the consideration of the soybean grain's angle of repose. It also has a slant base (27°) to enable seeds flow down and pass through the outlet.

Metering mechanism

The metering mechanism is a major component in a planter. It picks required number of seeds and delivers them into the soil through the delivery tube at required depths created by furrow openers.

The metering mechanism was made of aluminum disc; enclosed with a circular flat bar casing with a gap of 2 mm. The hole is expected to pick only one seed when it rotates in a vertical plane at the bottom of the hopper. It was mounted on a horizontal shaft which is driven directly by the side traction wheel.

Furrow opener

Furrow openers is the device that opens the soil where seeds metered out and falling through the delivery tube are dropped into the soil and covered. It was designed with an adjustable knife-like type formed from sheet metal of 3 mm thickness containing an angle iron of size 60 mm x 60 mm welded behind forming a 'v' shape to enable easy cutting through the soil cuts and pushing the soil sideways to form a furrow opener also permits planting an depth of the crop.

Determination of Size of furrow opener

The Furrow opener was made up of 5 mm mild steel angle bar with a length of 300 mm. The angle bar iron was fabricated to sharp knife-edge like structure to facilitate an easy cut through the soil. Nuts and bolts were used to fasten the device to the frame through a hole drilled on the frame.

Delivery tube

This is the tube through which seeds were metered out by the holes on the disc travel before they are deposited into the furrow. The seed delivery tube is located below the metering mechanism casing into which the metering plate releases the seed after picking the seeds from the bottom of the hopper.

Planter Frame

This is a bar on which the units of the planter are mounted. It also permits means of and also adjusting the planting spacing. planter units were attached to the bar with a U-bolt through a connecting frame.

Traction Wheels

These wheels are located at the side of the frame (planter components frame) at one end. The wheel was design to perform two functions which include; driving the metering plate, covering the metered seed and pressing the soil on the seeds for effective emergence to enhance movement on loose soils (is a motorcycle rear tires which have 540 mm in diameter).

Depth Control Wheels

Two depth control wheels, one on each side of the machine were provided. The wheels provide balance to the machine and helps in maintaining proper depth of sowing. The diameter of the wheel was 300 mm and rim width was 50 mm. The height of the wheels from the ground level could be adjusted to maintain the proper balance and appropriate depth of sowing

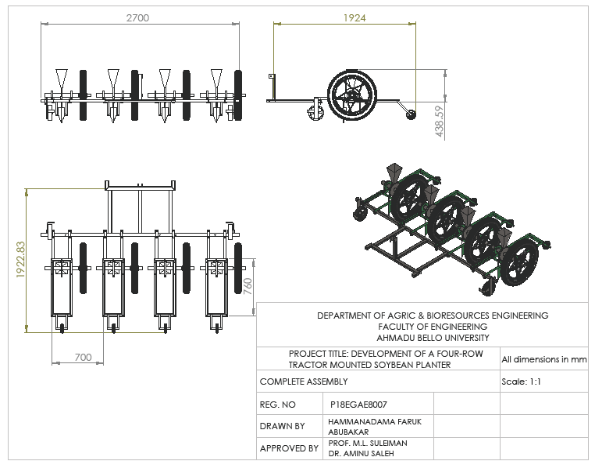


Figure 1 Isometric view of the developed planter

Design Parameters

The following parameters were considered in the development of the planter:

Weight of the Planter

Weight of the planter component acting on the wheel = W_m + Wh + Wfr + Wc………….(1)

(Khurmi and Gubta, 2005)
Where W_m= Weight of the metering plate (N)
Wh= Weight of the hopper (N)
Wfr· = Weight of the frame (N)
Wc = Weight of the metering casing (N)

Total Torque

$T = H_m x\ r_w$ ……………………………….(2)

$H_{m\,=}\ C.A + W\tan\phi$……………………….(3)

(Muhammad, 2010)

Where, H_m = Maximum thrust (KN)

$R_{w\ =}$ Radius of thre traction wheel (0.37005 m)

C = Soil cohesion, 13.5 KPa for sandy soil

ϕ = Soil frictional resistance, 0-20° for non-clay soil

W = Weight of the planter (Kg)

Determination of the shaft diameter

The shaft size was selected using the relationship given by (Hall *et.al*, 1980) as;

$$d^3 = \frac{16}{\pi \tau s} \sqrt{(K_b M_b)^2 + (K_t M_t)^2} \quad \ldots\ldots\ldots\ldots(4)$$

Where; d = shaft diameter

K_b, and K_t. = combine shocks and fatigue factors applied to bending and torsional moment respectively

M_b and M_t. = bending and torsional moment (N/m^2)

τ_s= allowable stress of the steel shaft (N/m^2)

Allowable shear stress for shaft without keyways, τ_s= least value of 0.3 yield strength and 0.18 ultimate strength of the shaft material (Kurmi and Gupta 2006)

The material selected for the shaft is mild steel (C 1040) with ultimate and yield strength of 770 and 580 MN/m^2 respectively.

$0.3(580) = 174\ MN/m^2$

$0.18(770)= 138.6 MN/m^2$

The smaller value is 138.6 MN/m^2 and further reduced by 25 due to the presence of key way

Allowable shear stress for shaft, τ_s= 34.65 MN/m^2

K_b= 1.5 to 2.0

and K_t= 1.0 to1.5 (Kurmi and Gupta 2006)

Determination of Number of Cells

The number of cells was determined using the expression below given by (Ibukun *etaI.*, 2014).

$$\text{Number of cells} = \frac{\pi dw}{Sc} \ldots\ldots\ldots\ldots(5)$$

Where; d_w = diameter of the planter ground wheel (mm)

Sc = intra row spacing of the seed (mm)

Determination of seed population

The seed population was determined by using equation as reported by (Soyoye *et* al., 2016)

$$P_s = n\left[\frac{A}{Sr\ Sc}\right] \ldots\ldots\ldots\ldots(6)$$

Where; P_s = actual number of seeds discharged

n = average number of seed discharge
A = area of the field (m²)
S_r = inter row spacing (cm)
S_c = intra row spacing (cm)

Fabrication and Assembling of the planter

The component parts of the developed four-row tractor mounted soybean planter was fabricated and assembly in the Department of Agricultural and Bio-Resources Engineering workshop, Faculty of Engineering, Ahmadu Bello University, Zaria. Figure 1 and 2 shows a tractor and the developed planter.

Working principles of the developed planter

The four (4) hoppers have a capacity of 11.10 kg soybeans seeds. A metering mechanism disc ensures one (1) single seed is pick in and delivered to the soil through the delivery chute. A press wheel is attached to the frame which will cover the seeds to ensure good germination. The metering device is a circular components of 195 mm diameter and was equipped with equal distance openings set 195 mm to enable equal spacing of crops planted within the rows. The planter is a tractor mounted; The orthographic view of the planter is shown in Figure 1.

Figure 1 Developed Soybean Planter mounted on the tractor planting on the field.

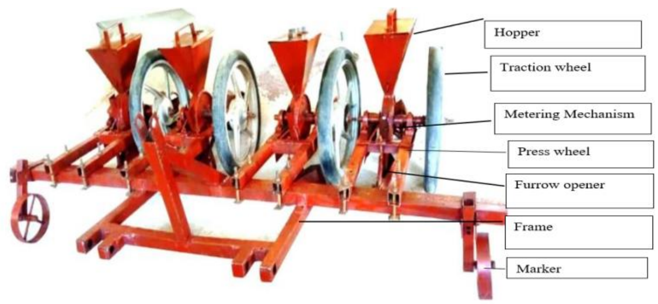


Figure 2 Developed Four-Row Tractor Mounted Soybean Planter

III. RESULTS AND DISCUSSIONS

The results of this research titled development of a four-row tractor mounted soybean planter are presented and discussed under the following sub-headings:

I. The developed Four-Row Tractor Mounted Soybean Planter and its principle of operation
II. Laboratory evaluation of the developed planter
III. Field evaluation of the developed planter.

Laboratory Evaluations

The developed planter was evaluated in the laboratory under the following headings:

Percentage Seeds Damage

The experiment was done in three sets: with the hoppers full, half-filled and one quarter filled. For each case, the planter was powered on by the tractor and allowed to move over five revolutions. At the end, the broken seeds and whole seeds metered were collected and weighed and the percentage seed damage was computed as shown in Table 4.1 below.

Table 1.1 Percentage seed damage

Sample No.	Ist Hopper Weight of whole seeds (g)	Ist Hopper Weight of damage seeds (g)	2nd Hopper Weight of whole seeds (g)	2nd Hopper Weight of damage seeds (g)	3rd Hopper Weight of whole seeds (g)	3rd Hopper Weight of damage seeds (g)	4rt Hopper Weight of whole seeds (g)	4rt Hopper Weight of damage seeds (g)
Full hopper	2082	41.64	2080	39	2085	40.7	2078	35.8
Half-filled hopper	1041	8.41	1040	8.6	1042.5	7.8	1039	6.8
Quarterly filled hopper	520.5	6.02	520	5.7	521.25	4.8	519.5	5.3
Average % damage		1.394%		1.464%		1.460%		1.315%

From Table 1 above shows that the percentage seed damage of the developed planter during the laboratory evaluation is very minimal as is less than 1.5%, which means that the developed planter is good for planting operation. This implies that the planter is mechanically efficient in the delivery of whole seeds to the soil, it shows that the developed planter has less seed damage than what Odunma *et al.*, (2014), obtained 2.34%, Olajide and Manuwa, (2014) obtained 2.5% and Bomgboye and Mofolasayo, (2006) of 3.51% respectively. Broken seeds reduce the number of seedlings that can emerge on a planted field. The higher the number of damaged seeds, the lower the plant population on the planted area. The developed planter has the capability of maintaining maximum plant emergence after planting in the field.

Seed Delivery Rate

The test was done in three stages for the developed planter. The first was with the hoppers full, the second was with the hoppers half-filled and the third was with the hoppers quarter-filled. At each stage, the planter was allowed to roll over five revolutions. The dropped seeds were then collected and weighed. Each stage was repeated thrice and the average values were obtained. The seeds delivery rate was found to be 48.2 kg/ha which is similar to what Agidi *et al.*,(2017) obtained as 47.7 kg/ha.

Evenness of spacing

Here spacing between plant-to-plant evenness was computed as reported by FAO, (1994) and was found to be 0.578, which is far (0.24) to what Upahi, 2017 obtained with his two-row ridge engine planter.

Field Evaluation

The developed four-row tractor mounted soybean planter was tested in the Agricultural and Bio-Resources Engineering Department of Ahmadu Bello University, Zaria Demonstration plot and discussed as follows under the followings headings:

Soil Moisture Content Determination

The results of the soil moisture content for the experimental plots were computed from the values obtained from laboratory determination. The results are presented in Appendix A. The moisture content was found in replication I, replication II and replication III as 24.19, 25.17 24.60 respectively. Figure 4a and 4.3b shows the soil sample collection in the field and laboratory analysis respectively.

Figure 4. Soybean planted with the Developed Planter arranged in 50 cm within rows and average 5.7 cm plant-to-plant spacing

Figure 4c. Showing soybean plants planted with a conventional planter at 80 cm within rows spacing and averages 20 to 30 cm plant-to-plant spacing**.**

Analysis of variance for soybean emergence in the field

The results of the soybean emergence in the experimental plot carried-out at the Agricultural and Bio-Resources Engineering Department's students experimental plot were taken from day 1 to 5 of its emergence and analyzed as follows:

Table: 2. Analysis of variance ANOVA for soybeans emergence

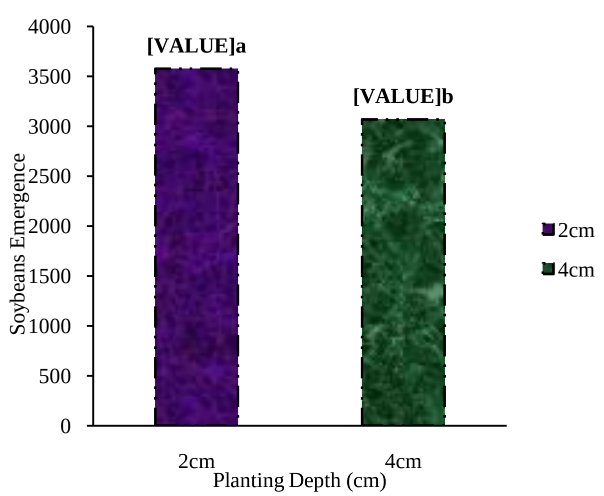
Source of Variation	df	SS	MS	F Value	Pr > F
Block stratum	2	352452.	176226.		
Block .Depth stratum					
Depth	1	1159765.	1159765.	336.05	0.003
Residual	2	6902.	3451.	0.04	
Depth*.Speed stratum					
Speed	2	2182406.	1091203.	12.79	0.003
Depth*Speed	2	935041.	467520.	5.48	0.032
Residual	8	682684.	85336.		
Total	17	5319250.			

From the Table 2. above we can see that there is a significant difference in the depth of planting, speed as well as the interaction between the depth and forward speed of the tractor.

Effect of Planting depth on emergence of soybeans

From the results obtained in the field shows that depth of planting has a significant different in the emergence of the planted soybean. At 2 cm depth of planting has the highest number of plants emergence than at 4 cm which is similar to what Odunma *et al.*, (2014) obtained at 2.22 cm. This might likely because the soil cover in 2 cm depth is less or small, the soybean has enough energy and can easily penetrate an emerge, while in the 4 cm depth the soil is thicker, so soybean used most of its energy trying to penetrate the soil cover as a result the emergence is delay and some soybean cannot be able to penetrate and subsequently died. From Figure 2.1 we can see that at 2 cm depth we have about 3754 plants emerge while at 4 cm depth we have about 3066.33 plants emerge. This implies that the developed planter can best be used to plant soybean at 2 cm.

Figure:2.1 Effect of Planting depth on emergence of soybeans

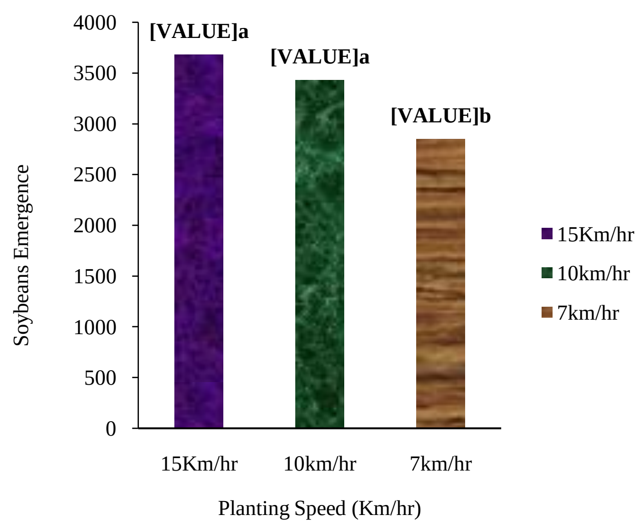


Means that do not share a letter are significantly different on the ranking as a and b.

Effect of Planting Speed on emergence of soybeans

The results showed that tractor forward speed has a significant difference on the soybean emergence. From Figure 2.2 we can see that at tractor forward speed of 15 km/hr gives the best planting tractor forward speed which is similar with Agidi, *et al.*, (2017) which says 16 km/hr is the optimum soybean tractor forward speed of planting. Then followed by 10 km/hr. while 7 km/hr gives the least soybean plants emergence, therefore, 15 km/hr. is the optimum tractor forward speed of planting with the developed planter. Alhassan and Adewumi, (2018), also reported that the speed of operation has an effect on the performance indices of the planter.

Figure:2.2 Effect of Planting Speed on emergence of soybeans

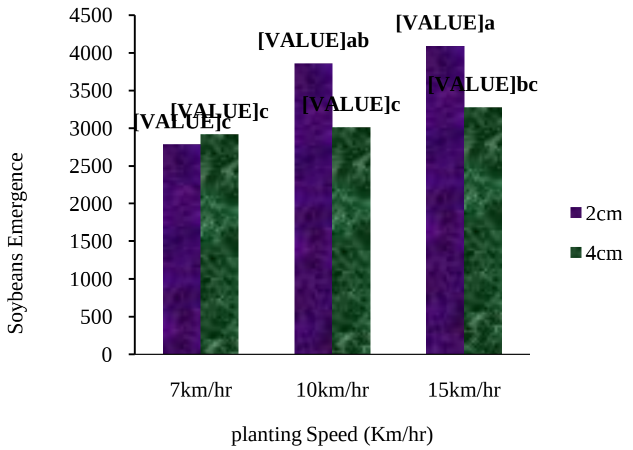


Means that do not share a letter are significantly different.

Effect of Planting Depth and Planting Speed on emergence of soybeans

The interactions between planting depth and speed of operation have significant effects on the soybean emergence. From Figure 2.3 we can see that a combination of 15 km/hr at 2 cm depth of planting gave the highest number of plants emerge recording 4086.67 plants, followed by 10 km/hr at 2 cm depth of planting gave 3854.33 plants emerge, which is similar to Bakhtiari and Longhavi, (2009) While at 7 km/hr gives the least plants emergence. Therefore, a combination of 15 km/hr at 2 cm depth is the best combination of planting soybean with the developed planter, followed by 10 km/hr at 2 cm planting depth.

Figure:2.3 Effect of Planting Depth and Planting Speed on emergence of soybean



Means that do not share a letter are significantly different.

IV. CONCLUSIONS

The four-row tractor mounted soybean planter was designed, constructed and evaluated both in the laboratory and on the field. The developed planter has the capacity for planting single seed per hole in one hectare in 2.7 hours. Seedling emergence under the developed planter was estimated to be 400,000 per hectare. The field capacity for the developed planter were 0.792 ha/hr. The average speeds of planting were 0.6 m/s. The average plant-plant spacing was 5.7 cm for the developed planter. It is therefore, concluded that the developed four-row tractor mounted soybean planter was efficient for optimum soybean plant population per hectare.

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