DESIGN AND FABRICATION OF THREE ROW TRACTOR DRAWN MULTI-SEED PLANTER WITH FERTILIZER APPLICATOR

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ABSTRACT
Owing to the importance of grain crops such as maize, soybean, cowpea, guinea corn etc. to the teeming population, urgent measures need be employed to ensure enhanced productivity in order to meet demand for food, and other requirements by man and animals, most of the existing planters are designed to plant specific crop whereas the three row multi-crop planter is design to plant different crops with the principle of changing the metering plates when required to plant another crop. The three row tractor drawn multi-seed planter made up of top and lower linkages, main frame, depth control wheel, fertilizer auger, and seed metering device, cage or metering wheel, furrow openers, hoppers and transmission system. Three different grain crops (soya beans, maize and cow pea) were planted. At the speed of 6.7, 6.5 and 7.2 km/hr., and at an average seed rate of 70.1, 61.6 and 49.9 kg/ha for planting soy beans, maize and cowpea, respectively. The average planting depth were 4.8, 4.3, 4.5, and 3.9 cm. The varying depth of planting recorded between the three crops shows uneven soil level condition which makes the planter to skip some areas of the land. Massive production and aggressive distribution to farmers should be highly encouraged and facilitated in order to substitute foreign importation of seeds planters and reduction of foreign currency exchange.

KEYWORDS: grain crop, multi-seed planter, fertilizer applicator, design and fabrication

1. INTRODUCTION

Grain crops such as maize, soybean, cowpea, groundnut etc. are the most important staple food in Nigeria. Humans get an average of 48 percent of their calories, or food energy from grains. Owing to the importance of these grain crops to the teeming population, urgent measures need be employed to ensure enhanced productivity in order to meet demand for food, and other requirements by man and animals. In grain crop production, one of the most important operation is planting. Over the years, manual, hand push and animal driven methods of planting have been employed particularly in developing countries.

Farmers in the rural areas use crude implements such as machete or sticks not just to sow different seeds but also to apply fertilizer to their crops; often times more than the required numbers of the seed and fertilizer quantity are dropped in a hole and covered. This results to an increase in production cost because extra man-hours will be required for thinning operation as excessive seeds is inevitably sown per hole in addition to the drudgery involved and the boring nature of the work (Oduma *et al.,* 2014). Excessive application of fertilizer will also lead to damage of the crop rather than increased crop yield.

Proper placement of fertilizer in relation to the seeds or plant roots is important for maximum response and the most efficient utilization of the nutrients, because movement of most fertilizers in the soil is very limited therefore, uniform distribution and proper placement of seed and fertilizer will continue to become increasingly important as factors in producing maximum crop response at minimum cost.

As a result of competition for grain crops by both man and animal, there is need to increase the supply level of the grains and this can only be achieved if appropriate use of agricultural machines are employed. Machine parts failure due to environmental factors attributed to the foreign planting machines and single crop plating machines developed by local fabricator and traditional methods of planting are time consuming and are associated with lots of drudgeries which result in low seed placement, low spacing efficiency, and health issues due to the longer hours required for careful hand metering of seeds if crowding or bunching is to be avoided (Kumar *et al*., 2015; Soyoye *et al*., 2016; Bamgboye and Mofolasayo 2006).

In Nigeria various types of planters designed and developed to suit the local conditions have been reported. Olajide and Manuwa (2014) developed a low-cost manually-operated hand pushed row crop planter capable of planting three types of grains- maize, soybean and cowpea. An average field capacity of 0.36 ha/hr. and efficiency of 71% with a percentage seed damage of 2.58%, spacing of 50.2 cm and an average depth of 4.28 cm were reported for the planter. Bamgboye and Mofolasayo (2006) developed a manually operated two-row planter. The field efficiency and field capacity were 71.75% and 0.36 ha/h while seed rate was 0.36kg/h with low average seed damage of 3.51%. Ikechukwu *et al*. (2014) designed and fabricated a manually operated single row maize planter for garden use and the field test results showed that the planter had a planting capacity of 0.0486 ha/hr. All of the above reported planters have got their obvious advantages both in efficiency and affordability. However, it is clear that most of the existing planters in Nigeria are manually operated, whereas, tractor drawn planters are usually preferred in large farms (Ani *et al*., 2016).

The drive towards mechanizing the agricultural sector in Nigeria will only yield the desired results if local engineers advance towards developing not only tractor drawn planters but also planters with high efficiency, low cost of procurement and maintenance. Besides the obvious limitations associated with the existing locally developed planters, the high cost of procuring their foreign counterparts, coupled with the problem of adaptability to the Nigerian climatic and soil conditions necessitate this development. Thus, this paper is aimed at developing a tractor drawn six row soybean planter that will plant soybean with uniform spacing and depth at minimal or no seed damage and at an increased field capacity and efficiency.

2. MATERIALS AND METHODS

2.1 Description of the Machine

The fabricated three row tractor drawn multi-seed planter comprises of the following components top and lower linkages, main frame, depth control wheel, fertilizer auger, seed metering device, cage or metering wheel, furrow openers, hoppers and transmission system. The machine is been fabricated majorly with mild steel taking 70% of the components, stainless steel 20% for fertilizer auger and delivery pipes and 10%of plastic for both fertilizer and seed hoppers.

2.2 Design Analysis

The design analysis was carried out with a view to evaluating the necessary design parameters, strength and size of materials for consideration in the selection of the various machine parts in order to avoid failure by excessive yielding and fatigue during the required working life of the machine as shown in Fig. 1 and 2, respectively.

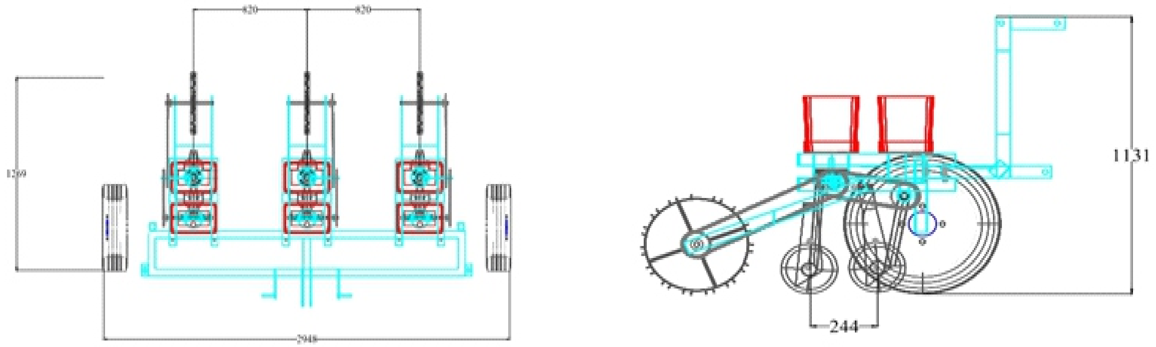

Fig. 1. Orthographic view

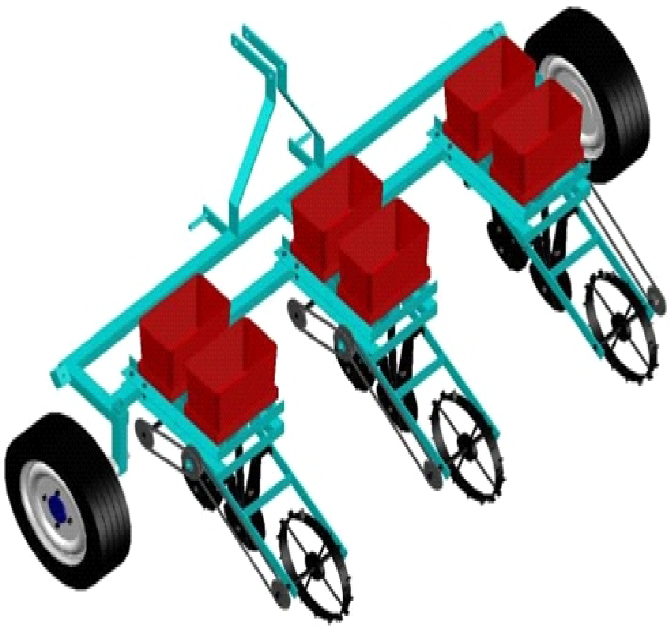

Fig. 2. Isometric view of the multi-seed planter

2.2.1 Weight of the frame

The weight of the rectangular frame was calculated in order to know the amount of load being exerted on the frame by other components of the planter. Therefore the weight of the frame was computed using the following equation: (Gosa and Ayelew 2019)

$$W = mg \tag{1}$$

and

$$m = \rho v \tag{2}$$

where, W = weight of the frame (N), M = mass of the frame (kg), g = acceleration due to gravity (m/s^2), ρ=*density of the frame* (kg/m^3), v = volume of the frame (m^3)

But $V = L \times B \times H$ (3)

Where, L = Length of frame (m), B = Breadth of frame (m), H = Height of frame (m)

2.2.2 Total length of the frame

This was determined as a function of the three furrow openers spaced uniformly from each other on the frame:

$$L = 5s + 2f \quad (4)$$

Where, L = Total length of the frame (m), s = Uniform distance between furrows (m), f = Distance from the edge of the frame to the first and last furrow opener (m)

2.2.3 Length of the chain

Chains were used to transmit power from cage or metering wheel using sprockets to seed metering device and fertilizer auger to get the design intra row spacing. The length was calculated using the formula computed by Khurmi and Gupta (2005).

$$L = 2(C) + \left(\frac{F}{4} + \frac{R}{4} + 1\right) \quad (5)$$

where: L = Length of chain (m), C = Center to center distance of both sprockets (m), F = Number of teeth on front sprocket, R = Number of teeth on rear sprocket

2.2.4 The speed of the chain

The speed of chain was determined by using the expression in Equation 6 (Khurmi and Gupta, 2005),

$$V = \frac{P \times T \times N}{1000} \quad (6)$$

Where, V = Speed of chain (m/s), P = Chain pitch (m), T = Number of teeth, N = Revolution per minute of the wheel (rpm)

2.2.5 Forces acting on the frame

Resolving forces acting on the frame/ furrow opener assembly vertically is determine using the relationship below

$$Fv = W\cos\theta \quad (7)$$

Where, Fv = Vertical force (N),W = Weight of frame with the furrow opener (kg) and other components, θ = Angle of inclination of the furrow opener (°)

2.2.6 Determination of the Capacity of the Seeds and Fertilizer Hoppers

The seeds and fertilizer hoppers were design based on the capacity of a rectangular tank. The capacity of both seeds and fertilizer hoppers of this planter was designed according to the principle of determining volumetric capacity of hoppers of the planter. 7.48 is a constant of gallons per cubic foot is used the relations for calculating the capacity (Babatunde, 2020)

$$A = L \times W \quad (8)$$
$$V = A \times H \quad (9)$$
$$C = V \times 7.48 \quad (10)$$

Where, A = Area of the rectangular tank (m^2), L = Length of the rectangular tank (m), W = Width of the rectangular tank (m), V = Volume of the rectangular tank (m^3)

2.3 Field Test of the Machine

The planter was hitched to a 75 Hp, New Holland TT75 tractor the depth of penetration, the planting depth was control by the hydraulic system and the side wheels can also be used as depth control.

The three row tractor drawn multi-seed planter was tested to ascertain in performance, furrow opening efficiency and seed germination percentage on 1 hectare ploughed and harrowed land at National Centre for Agricultural Mechanization (NCAM) Ilorin, Nigeria in September, 2021 during the rainy and planting season. From a desired starting point, the planter was lowered and adjusted to meet up the recommended depth of 5cm for planting soybeans with the aid of the upper and two lower links of the tractor.

2.3.1 Speed of Operation

To determine the tractor operation speed during planting, the time required for covering 138 m row length was recorded with digital stop watch. Five measurements were recorded in each plot and mean values were computed as km/hr.

$$Speed\left(\frac{km}{hr}\right) = Distance\frac{m}{Times}(s) \times 3.6 \qquad (11)$$

2.3.2 Determination of Theoretical field capacity (TFC)

Theoretical field capacity, T_{FC} is the rate of field coverage of an implement that would be obtained if the planter were performing its function 100 % of the time at the rated forward speed and always covered 100 % of its rated width. It is expressed as hectare per hour and determined as:

$$TFC = \frac{W \times S}{10} \qquad (12)$$

Where, TFC = Theoretical Field capacity, (ha/hr.), W = Effective width of implement, (m), S= Speed of operation, (km/hr.)

2.3.3 Determination of Effective Field Capacity, EFC

It is the actual average rate of coverage by the machine divided by time taken. It is expressed as:

$$EFC = \frac{A}{T} \qquad (13)$$

Where, EFC = Effective field capacity, (ha/hr.), A = Actual area covered, (ha), T = Time required to cover the area, (hr.).

2.3.4 Determination of Field Efficiency, F_e

Field efficiency is the ratio of effective field capacity to theoretical field capacity. It is expressed

$$FE(\%) = \frac{EFC}{TFC} \times 100\% \qquad (14)$$

Where, F_e= field efficiency, %, EFC= effective field capacity, ha/hr., TFC = Theoretical field capacity, ha/hr.

2.3.5 Fuel consumption

The fuel consumption was measured by refill method. The fuel tank of the tractor was filled to full capacity and run at constant speed. After completion of the test plot, the fuel was refilled in the tank up to its full capacity. The quantity of refilled fuel computed to fuel consumption in litter per hour and litter per hectare.

2.4. Sowing Parameters

2.4.1 Seed Rate

The seed rate was determined by taking the weight of seeds before and after sowing operation. Then subtracted the final weight of seed from initial weight of seed so that the seed rate was obtained and the results were expressed in terms of kg ha^{-1}. This was established considering the weight of seeds planted per hectare. (Aniekwe and Mbah, 2014).

$$\text{Seed Rate (Kg ha-1)} = \frac{\text{Mass}}{\text{Area of the plot}} \quad (15)$$

2.4.2 Planting Depth

The depth of the sowing was determined by measuring with two steel rule, one placed horizontally across the surface of soil along the sown rows, how deep the furrow openers could penetrate into the soil. The average depth of the seeds sown was determined by randomly measuring the depth of ten sampled furrow with the use of two calibrated steel rules by placing one horizontally while the other vertically for the taking reading.

2.4.3 Germination Percentage

The germination percentage was determined by marking out and counting the number of seeds drilled within a given area at different points. The number of seeds that germinated after three weeks was also counted and was expressed as percentage relative to the seeds number of seeds drilled originally at each point as follows: (Agidi *et al.*, 2017)

$$G_r\ (\%) = \frac{S_g}{S_d} \times 100\% \quad (16)$$

Where, - $_r$ = Germination is rate (%); S_g = number of germinated seeds; S_d = Number of drilled seeds

3. RESULTS AND DISCUSSION

The three row tractor drawn multi-Seed planter with fertilizer applicator has been successfully designed and fabricated as shown in Fig. 3. The results obtained from the testing of the machine are presented in Table 1.

Fig. 3.The fabricated three row tractor drawn multi-seed planter with fertilizer applicator

Table1. Crops, field replicates and field parameters

S/N	Crop	Replications	Depth of planting (cm)	Seed Rate (Kg/ha)	Speed (km/hr)	Germi nation (%)	EFC (ha/hr.)	TFC (ha/hr)	F_e (%)
1	Soya beans	1	5.0	71.2	6.7	81.2	2.10	3.32	62.36
		2	4.9	69.0	7.2	75.5	2.50	3.67	68.11
		3	4.5	70.1	8.2	67.6	3.00	4.31	69.60
2	Maize	1	4.6	63.3	6.5	83.5	1.40	1.81	77.39
		2	4.2	57.4	7.5	76.4	1.80	2.50	72.00
		3	4.0	64.2	8.6	80.7	2.00	3.00	66.65
3	Cow pea	1	3.6	55.4	7.2	78.2	0.50	0.52	96.15
		2	4.0	46.3	8.0	70.1	0.30	0.45	66.67
		3	4.1	48.0	8.5	60.4	0.31	0.50	62.00

The results of three different grain crops (soy beans, maize and cow pea) planted with their respective planting speed, depth of planting, seed rate and other field parameters are presented in Table 1. At the speed of 6.7Km/hr., the machine planted soy beans at high seed rate of 69.0 kg/ha – 71.2kg/ha and at the planting depth of 4.5-5.0cm with field efficiency of 62.36%. These values are well comparable with the values reported by Agidi *et al.* (2017) in their work on the design, fabrication and testing of a tractor drawn soybean planter. The field efficiency of maize was 77.39% at an average seed rate of 57.74 to 64.2 kg/hr. with the planting depth ranging from 4.0 to 4.6 cm. This indicates that the speed has significantly improved on the planting performance of the machine. The machine planted cow pea at highest field efficiency (EF) of 87.50% with drop in seed rate of 46.9 to 50.4 kg/hr and planting depth of 3.6 to 4.0 cm, respectively. The varying depth of planting recorded between the three crops shows uneven soil level condition which makes the planter to skip some areas of the land.

4. CONCLUSION

A three row tractor drawn Multi-seed planter designed, fabricated and tested successfully, the optimum performance (81.2%, 83.5% and 78.2% seed germination efficiency) was achieved by the planter with tractor/implement speed of (5.0km/hr., 4.6km/hr., and 3.6km/hr.) for soya bean, maize and cow pea, respectively.

The introduction of the three row tractor drawn multi-seed planter with fertilizer applicator will reduce drudgery and displace labour force which will be channeled into other productive activities of crop production. Massive production and aggressive distribution to farmers should be highly encouraged and facilitated in order to substitute foreign importation of seeds planters and reduction of foreign currency exchange.

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