African Journal of Agriculture and Food Science
ISSN: 2689-5331
Volume 6, Issue 1, 2023 (pp. 86-99) www.abjournals.org

DESIGN, FABRICATION AND PERFORMANCE EVALUATION OF A MOTORIZED 2 – ROW SOYBEAN PLANTER FOR SMALL SCALE FARMERS IN KATSINA STATE

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Cite this article:

Abubakar Y., Abdulbasit O.I. (2023), Design, Fabrication and Performance Evaluation of a Motorized 2 – Row Soybean Planter for Small Scale Farmers in Katsina State. African Journal of Agriculture and Food Science 6(1), 86-99. DOI: 10.52589/AJAFS-EMS24XWI

Manuscript History

Received: 17 March 2023

Accepted: 24 May 2023

Published: 24 May 2023

ABSTRACT: *A 2 – row soybean planter has been fabricated according the design specifications and field performance of the planter was evaluated on 0.5 ha (500 m^2) plot of land on the college farm of Federal College of Education, Katsina. Five (5) levels of speed of operation (0.42 m/s, 0.56 m/s, 0.69 m/s, 0.83 m/s and 0.97 m/s) were used to evaluate performance of the fabricated planter. Results of performance evaluation of the fabricated planter reveal that 0.83 m/s speed of operation produces planting parameters with values that are very close to the recommended planting parameters of soybean TGX 1448 – 2E. Thus, indicating that 0.83 m/s is the best speed of operation of the fabricated planter with mean value of 24.72 kg/h seeding rate, 98.14 % uniformity of spacing, 78.05 % planting efficiency and 7 broken seeds per 100 seeds. The analysis of variance at P > 0.05 reveals that speed of operation has a positive effect on the seeding rate and field capacity; a negative effect on planting efficiency of the fabricated 2 – row soybean planter. Thus, seeding rate and field capacity increases with increasing speed while the planting efficiency decreases with increasing speed of operation. Functional performance test results indicate a significant relationship of the speed of operation with seeding rate, field capacity and planting efficiency of the planter whereas uniformity of spacing and percentage damaged seeds are relatively un affected by the speed of operation of the planter.*

KEYWORDS: Field Capacity, Planter, Planting Efficiency, Seeding Rate, Soybean

Article DOI: 10.52589/AJAFS-EMS24XWI
DOI URL: https://doi.org/10.52589/AJAFS-EMS24XWI

INTRODUCTION

Planting also known as seeding or sowing refers to placing seeds into the soil for germination. It is one of the most important cultural practices in crop production. The objectives of planting operation is to put the seeds in rows at the desired depth with uniform seed to seed spacing and cover the seeds with soil. There are different methods of planting practiced in crop production. These methods are broadly classified as direct seeding, transplanting and vegetative propagation (Moymoykimkim, 2017). The direct seeding is the methods of planting adopted were seeds are directly placed into the soil for germination in arable crop production. According to Yokesh (1998), the most common direct seeding methods of planting are broadcasting, dibbling, check row planting and drilling. Generally, these operations of direct seeding can be achieved either manually or by the use of mechanical planting equipment. The manual method of planting is the most common method of direct seeding used by small scale farmers especially in the rural areas. It involves the use of traditional tools such as hoe and cutlass for making holes or slits and dropping seeds by hand. Manual method of planting is labour-intensive and a tedious activity as it requires 3 – 5 hours of man-labour per hectare (Swapnil *et al.*, 2017). According to Jadhao (2019), the manual method of direct seeding is associated with non uniformity in distribution of seeds, limiting size of field that can be planted, poor control over depth of planting, uncontrolled high seeding rate, improper germination of seeds and inaccuracies in seed placement and spacing. The mechanical direct seeding is the use of machine to perform planting operations. It has been one of the most significant developments in crop production. The largest part of crop production increase can be attributed to the increased utilization of mechanical energy supplied by effective planting machines. Alfred (2015) pointed out four different types of mechanical direct seeding equipment depending on the type of crop and the planting pattern. These are:

i. Broadcaster: This is a planting machine that distributes seeds at random on the soil surface. It has only a means of regulating the seed rate (quantity of seed to be planted per given area).

ii. Seed drill: This is a planting machine that plant by randomly dropping seeds in furrows to form definite rows of plants. It has an arrangement that can be used to vary the distance between rows of plant in addition to seed rate regulator.

iii. Precision planter: This is a planting machine that plant seeds at regular and uniform distance along rows. It has a means of regulating seed rate in addition to an arrangement that can be used to vary the planting depth, the intra and inter spacing.

iv. Dibble planter: This is a planter that place seeds or number of seeds in discrete holes which are spaced equally and aligned to form rows.

According to Murray *et al.* (2006), direct seeding equipment possesses one or two of the following: a means of regulating the seed rate, a means of varying the depth of planting, a means of varying the distance between rows and a means of varying the distance between plants along a row. Therefore, to simplify human efforts in planting and reduce level of adoption of manual labour, various efforts have been made towards the development of mechanical planting devices using locally sourced materials. These efforts results to various achievements made by different

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researchers for the development of direct seeding equipment for planting various crops such as Cowpeas, Groundnut and Maize. Some of these researchers include Gambari *et al.* (2017) developed a manually operate 2 – row maize planter, John and Igwe (2014) developed a manually operated cowpeas precision planter, Gbabo et al. (2017) developed a tractor mounted planter.

Statement of problem/Justification

Optimum plant population and crop productivity relies on accurate seeding rate, planting depth, regular inter and intra spacing. The manual method of planting cannot achieve the above planting parameters thereby lead to low yield. However, manual method of planting soybean is the most popular and common among the small scale farmers in Katsina state because the factory manufactured planters are beyond the financial capability these farmers. Furthermore, affordable and simple technology for planting soybean is unavailable to small scale farmers especially in the rural areas of the state. Therefore, to reduce the level of manual labour and simplify human effort in planting and improve soybean production in Katsina state, there is the need to provide an alternative and replace the tedious manual method of planting with intermediate technology for planting to increase productivity.

Objectives of the research

The objectives of this research are as follows:

i. To design and fabricate a motorized 2 – row soybean planter using locally sourced materials.

ii. To evaluate field performance of the developed planter.

Research hypothesis

There is no significant relationship between speed of operation and seeding rate, plant spacing, field capacity and planting efficiency.

MATERIAL AND METHODS

Design considerations

The following considerations were used in design of the planter:

i. Availability of construction materials: All materials and equipment for the fabrication process of the planter should be sourced locally.

ii. Axial dimension of soybean seed: The planter should plant soybean seeds of different shape and size.

iii. Mode of operation: Planting operation of the planter should be motorized.

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iv. Field operation: The recommended seeding rates, field capacity, inter and intra row spacing of soybean should be achieved.

Design computations

i. Height of the hopper was obtained from equation 1 (Upahi, 2009).

$$H_c = R_w (n_b + 1) = 0.129 (1 + 1) = 0.258 \text{ m} = 258 \text{ mm} \quad (1)$$

Where

H_c is heigth oh hopper, mm; R_w is width of row = 0.129 m; N_b is hopper discharge points = 1

ii. Volume of the hopper was obtained from equation 2 (Upahi, 2009).

$$V_h = \frac{1}{3} [0.5(a + b)h]d \quad (2)$$

$$V_h = \frac{1}{3} [0.5(0.165 + 0.05)0.26]0.17 = 0.00158 \text{ m}^3$$

Where

V_h is hopper volume (m^3), a is upper length of hopper = 0.165 m, b is bottom length of hopper = 0.05 m, h = is height of hopper = 0.26 m.

iii. Hopper capacity was obtained using equation 3 (Kumar, 2018)

$$C_h = \gamma_d \text{ x } V_h = 788.24 \text{ kg/m}^3 \text{ x } 0.00158\text{m}^3 = 1.25 \text{ kg} \quad (3)$$

Total capacity of hoppers = 1.25 kg x 2 = 2.5 kg.

iv. The number of seed cell on the metering plate of the developed planter was computed calculated using equation 4 (Soyoye *et al.*, 2018).

$$C_N = \frac{\Pi D_w \; X \; T2}{S \; X \; T1} = \pi\,(0.3333)\,\frac{0.508\ m}{0.150\ m} = 4 \text{ seed cells} \quad (4)$$

Where

D_w is measured diameter of drive wheel = 0.572 m, S is seed spacing on a row = 0.150 m; T_1 = 42 teeth (63.5 mm Ø standard sprocket), T_2 = 14 teeth (150 mm Ø standard sprocket).

v. Diameter of the seed plate was determined using equation 5 reported by Gambari *et al.* (2017).

$$d_m = \pi \frac{S}{C_N} = \frac{3.142 \text{ x } 150 \text{ mm}}{4} = 117.83 \text{ mm} \quad (5)$$

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Where,

d_m = diameter of metering plate (mm), S = seed spacing on row = 150 mm; C_N = number of seed cells on the metering plate = 4

vi. Wheel shaft diameter was determined using equation 6 reported by Khurmi and Gupta (2005) as used by Gbabo *et al.* (2017) and Adekanye *et al*. (2019).

$$d^3 = \frac{16}{\pi S} \times [(K_b M_b)^2 + (K_t M_t)^2]^{1/2} \quad (6)$$

Where

d is shaft diameter (m); S is allowable stress = 5.63 MPa (Nm^{-2}), K_b is shock and fatigue factor applied to bending moment = 0 ; M_b is bending moment = 0 (Nm); K_t is shock and fatigue factor applied to torsional moment = 2.5; Mt is torsional moment = 23.18 (Nm).

Maximum permissible load on the wheels as stipulated in S224.1 of ASAE (2005) standard is 90.7 kg. For this design, 90 kg maximum load was taken.

Load on shaft = ½ maximum load + Sprocket = ½ (45 + 0.0125) = 45.01 N

Therefore, torque on shaft = Load x wheel diameter = 45.01 N x 0.508 m x = 22.87 Nm

Assuming that no torsional bending along shaft, allowable stress S_s = 5.63 MPa, Shock and fatigue factor K_t =1.5 to 3.0 (Spotts, 1988). With more shock load expected during operation, K_t = 2.5 was chosen for the design.

Diameter of the wheel shaft was calculated as $D^3s = \frac{16}{\Pi S_s}\sqrt{(K_t M_t)^2}$ (Khurmi and Gupta, 2005) $= \frac{16}{\pi\,(5.63\ X\ 10^6}\sqrt{(2.5\ X\ 22.87)^2} = 9.045 \times 10^{-7} \times 57.18 = 0.0373$ m = 37.3 mm

A 40 mm diameter shaft was chosen for wheel shaft.

vii. Load on the metering shaft was determined using load distribution diagram. The bending moment was computed using equation 7 and equation 8 as reported by Yinusa and Ajav (2015).

$$R_1 + R_2 = R_{h1} + R_{h2} + R_{sp} + R_{h3} \quad (7)$$

$$M_b = - R_{h2}(X_1) - R_{h1}(X_2) + R_1(X_3) \quad (8)$$

Where

R_1 and R_2 represent the load to the left and right drive wheels; R_{h1} equals to R_{h2} is load due to the first hopper = 23.75 N; R_{sp} = Load due to the sprocket = 12.5 N.

R_2 = 33.75/0.9 = 37.5 N, R_1 = 60 – 37.5 = 22.5 N and Maximum bending moment = 6.88 N

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viii. Stress on the shaft was determined from equation 9 reported by Khurmi and Gupta (2005) and used by Gbabo *et al.* (2017).

$$\tau_{max} = \frac{16}{\pi d^3} \left[(M^2 + T^2) \right]^{1/2} = 0.005 \text{ Nm} \quad (9)$$

Where

τ_{max} is maximum stress N/m; d is metering shaft diameter = 30 mm; M is bending moment of shaft = 6.88 Nm; T is torque = 22.87 (Nm).

ix. Power required to operate the planter was determine using equation 10 as reported by Upahi, (2009).

$$P_R = P_{wh} + P_{mm} + P_{sr} + P_{opr} \quad (10)$$

Where

P_{wh} is power to turn the wheels = 2Tω = 2(22.87 N x 3.497 m/s) x 0.00134 hp = 0.214 hp

P_{mm} = P_{wh} = 0.214 hp, P_{sr} is effective horizontal force x av. speed = 3461.49 N x 0.75m/s x 0.00134 hp = 3.48 hp, P_{opr} is operator's av. weight x average speed = 637.65 x 0.75 m/s x 0.00134 hp = 0.64 hp.

Minimum power requirement to operate the planter is 2 (0.214) + 3.48 + 0.64 = 4.5 hp. Therefore, a power generator of 5.0 hp was chosen for this design.

x. Transmitted speed from wheel to metering device was computed using equation 11 (Alhassan *et al.*, 2018).

$$\frac{N2}{N1} = \frac{D1}{D2} \quad (11)$$

Where

D_2 = Effective diameter of selected sprocket at metering (177. 79 mm), D_1= Effective diameter of selected sprocket at motor (63.5mm), N_1 = Speed at wheel (rpm), N_2 = Speed at metering (rpm).

$$N_1 = \frac{177.79}{63.5} \times 1 = 2.79 \text{ m/s} = 3 \text{ m/s}$$

Speed ratio = 1:3

Circumference of metering plate (C_{mp}) = π d_p= π (207.37) = 651.56 mm

Number of revolution of metering plate with respect to translational speed of the drive wheel was obtained.

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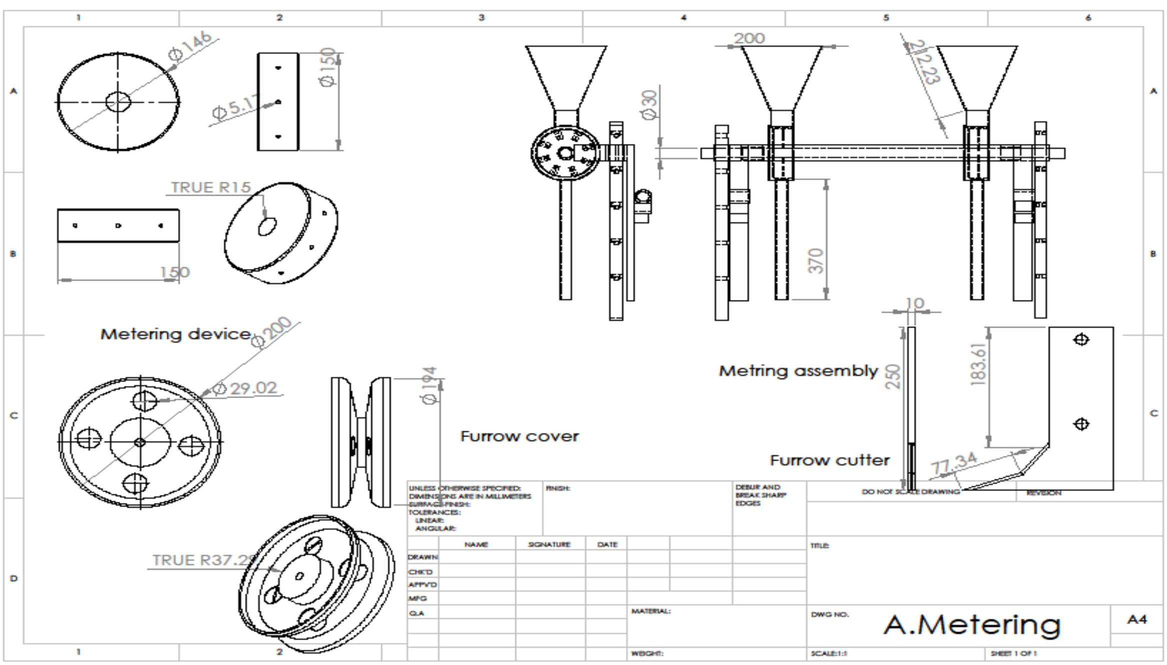
$$rpm_{plate} = \frac{60(1000)}{651.56} = 92.09 \text{ rpm},$$

$$\frac{rpm\ (plate)}{rpm\ (wheel)} = \frac{92.09}{32.40} = 2.84 = 3 \qquad \text{Reduction ratio} = 1:3$$

Design drawing of components



Exploded view of the planter

ISSN: 2689-5331
Volume 6, Issue 1, 2023 (pp. 86-99)
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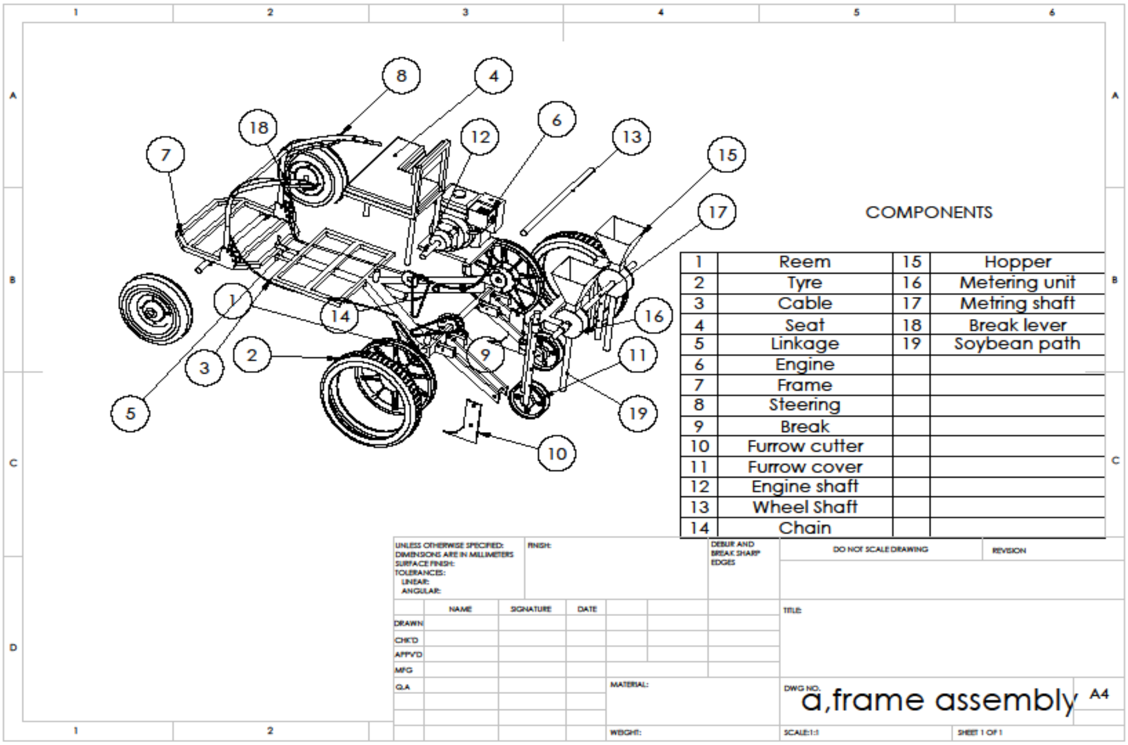

Technical characteristics of the planter

Part/ Component	Number	Characteristics	Function
Hopper	2	Height – 258 mm Volume – 0.00158 m^3 Capacity – 1.25 kg per hopper	Contain seeds to be planted
Seed plate	2	Diameter – 117.83 mm Seed cell size – 5.2mm No. of cells - 4	Seed metering
Delivery tube	2	Diameter – 25.4 mm Length - 205 mm	Seed transport
Furrow opener	2	Height of tine – 368.3 mm Max. depth of cut – 44.45 mm Row spacing – 381.0 mm	Create furrow along the rows
Press wheel	2	Diameter – 105 mm Spacing – 305 mm	Firming soil around planted seed.
Sprocket on metering shaft	1	Diameter – 159.94 mm	Power transmission to metering device
Sprocket on wheel shaft	1	Diameter – 63.5 mm	Power transmission wheel to metering shaft

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Pulley at engine end	1	Diameter – 190.5 mm	Power transmission from generator to engine gear box
Pulley at generator end	1	Diameter – 50.0 mm	Power transmission generator to gear box
Metering shaft	1	Length – 914.5mm	Drive the metering
	1	Diameter – 30.0 mm	mechanism.
Drive wheel shaft	1	Diameter – 40.0 mm	Drive wheel movement
		Length – 1000 mm	Power transmission
Belt drive	1	V-belt, A 39, 12.5 – 1050	
	-	Length 1050.89 mm	Power transmission
Chain drive		Length 1107.7 mm	
Power requirement		5.0hp	Power generation

Evaluation of field performance of the planter

The fabricated 2 – row soybean planter was evaluated by conducting field test at five levels of speed of operation (0.42m/s, 0.56 m/s, 0.69 m/s, 0.83 m/s and 0.97 m/s) to ascertain the functional performance of the planter. The performance evaluation was carried out using TGx 1448 – 2E soybean seeds on 5,000 m^2 (0.5 ha) land area for the determination of the following planting parameters determined at various speed of operation.

i. Seeding rate of the planter at four different speed of operation from each hopper was calculated using Equation 12 (Upahi, 2009).

$$\text{Seed rate per hopper} = \frac{\text{Total seeds collected from the hopper (kg)}}{\text{Average area covered during operation (ha)}} \qquad (12)$$

ii. Percentage uniformity of seed spacing on the three rows was determined using Equation 13 (FAO, 1994).

$$E_s = \frac{\mathrm{E_s} - \overline{\mathrm{SD}}}{\mathrm{E_s}} \times 100 \qquad (13)$$

Where; $\overline{E}_s$ = percentage uniformity of seed spacing, cm; E_s = average seed spacing, cm; SD = Standard deviation

iii. Percentage damaged seed at different speed of operation was calculated using Equation 14 (Kumar, 2018).

$$\text{Percentage damaged seeds} = \frac{\text{Average weight of broken seeds}}{\text{Total weight of seeds collected}} \times 100 \qquad (14)$$

iv. Effective field capacity of the developed planter was determined by using Equation 15 (Srivastava, 2006).

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$$C_{efc} = \frac{A}{T_{pr} + T_{np}} \quad (15)$$

Where; C_{efc} = the effective field capacity, ha/h; A = area covered, ha; T_{pr} = productive time, h;

T_{np} = non-productive time, h.

v. The field efficiency was calculated from Equation 16 (Kepner *et al.*, 1987).

$$\varepsilon = \frac{T_e}{T_t} \quad (16)$$

Where; ε= the field efficiency of the planter, %; T_e = effective time during operation, h;

T_t= Total time taken for the operation = effective time + time lost, h

RESULTS AND DISCUSSION

The results of performance evaluation of the fabricated 2 – row soybean planter is presented in figure 1.

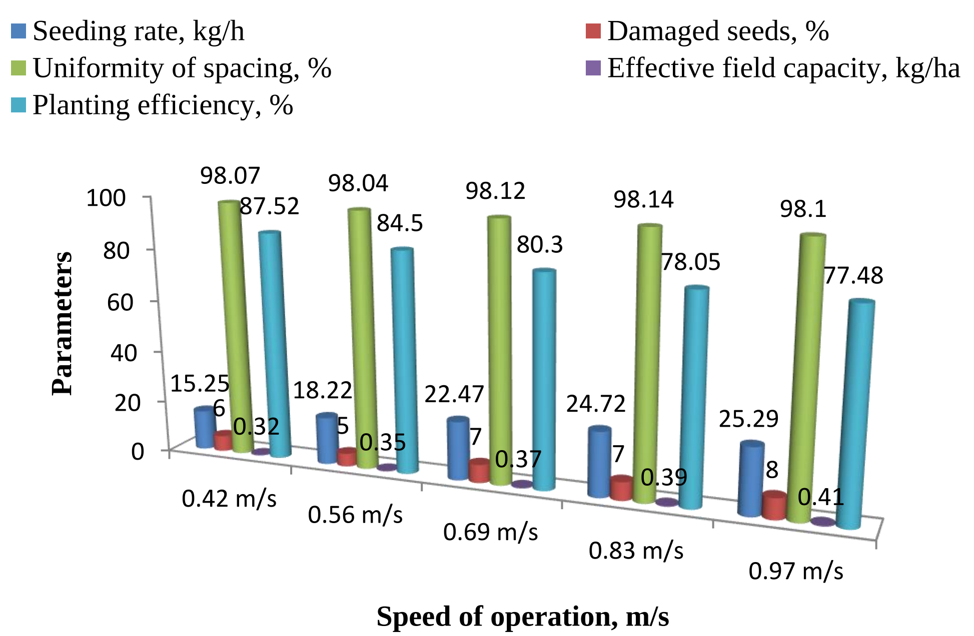

Figure 1: Field Performance of the 2 – Row Soybean Planter

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Performance evaluation of the planter was conducted with the two hoppers full to design capacity. The planter was operated at five levels of speed 0.42 m/s, 0.56 m/s, 0.69 m/s, 0.83 m/s and 0.97 m/s. The performance test results shows that the mean seeding rate of the planter ranges from 15.25 kg/h at the speed 0.42 m/s to 25.29 kg/h at 0.97 m/s which translate to the increase in seeding rate of 39.69% due to increase in the speed of operation. The speed of 0.97 m/s of the fabricated 2 – row soybean planter produce a seeding rate which is within the range of the recommended seed rate of soybean as reported by Dugje *et al* (2006). The result of field performance reveals that the fabricated planter has a very negligible change in the spacing on rows which indicate a high percentage of uniformity of spacing among the five different speed of operation. The percentage uniformity of spacing ranges from 98.04% to 98.14%. Narendra *et al.* (2012) reported similar trends in the uniformity of spacing from the result on performance evaluation of mechanical planters. The fabricated planter 2 – row soybean planter has the highest percentage of damaged seeds at 0.97 m/s speed of operation. The percentage damaged seeds was 2.5 % at 0.42 m/s, 3.0 % at 0.56 m/s, 3.5 % at 0.69 m/s and 4.0 % at 0.97 m/s. The results clearly indicate that percentage damaged seed increase with increasing speed of operation of the planter. Upahi (2009) presents a similar result on damaged seeds from performance evaluation of engine propelled soybean planter. The results of field performance evaluation of the fabricated 2 – row soybean planter shows that effective filed capacity of the planter increase with increase in the speed of operation of the planter. The increase in effective field capacity was as a result of higher seeding rate due to high speed. The mean effective field capacity of the planter was 0.32 kg/ha at 0.42 km/s speed, 0.35 kg/ha at 0.56 m/s, 0.37 kg/ha at 0.69 m/s, 0.39 kg/ha at 0.83 m/s and mean effective capacity of 0.41 kg/ha at the speed of operation of 0.97 m/s. These results were similar to the report of Alhassan *et al*. (2018) on the development of a self propelled multi – crop 2 – row precision planter. The results from functional performance test for performance evaluation of the planter reveals that the planting efficiency decreases with increasing speed of operation. The mean planting efficiency of the planter was 87.52 %, 84.55 %, 80.30 %, 78.05 % and 77.48 % for the speed of operation of 0.42 m/s, 0.56 m/s, 0.69 m/s, 0.83 m/s and 0.97 m/s respectively. The field evaluation result has shown that the planter has minimum planting efficiency of more than 75 % indicating a satisfactory performance compared to similar results reported by Oduma *et al.* (2014) on performance evaluation of a locally developed 3 – row maize planter.

The relationship between seeding rate, uniformity of seed spacing, effective field capacity planting efficiency and speed of operation of the planter is presented in Table 2.

Table 2: Analysis on speed of operation of the planter and selected planting parameters

	Variables Seed rate	Uniformity of spacing	Effective field capacity	Planting efficiency
Field trials, N	15	15	15	15
F ratio (5%)	146.25*	0.29	366.67*	89.15*
Coefficient of variation, R^2	0.21	0.27	0.19	0.73

Source: *ANOVA* **Significant at 5% level*

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Result from the analysis of variance as presented in Table 2 shows a coefficient of variation R^2 of 0.21, 0.27, 0.19 and 0.73 on seeding rate, uniformity of spacing, effective field capacity and planting efficiency respectively in relation to speed of operation of the planter. The functional performance test results has shown that the speed of operation affect seeding rate, effective field capacity and planting efficiency of the planter. The analysis of variance at $P > 0.05$ reveals a significant relation of the seeding rate and field capacity with speed indicating a positive effect on the seed rate and field capacity of the fabricated planter. Thus, the seeding rate and effective field capacity increases with increasing speed of operation. The analysis further shows significant relation of the planting efficiency of the planter with functional performance test result at different speed indicating a negative effect on the planting efficiency. Thus, the planting efficiency decreases with increasing speed of operation.

CONCLUSION

A 2 – row soybean planter has been fabricated at a very low cost compared to factory manufactured planter. The planter was evaluated on the field at different speed of operation. Performances of the fabricated planter in terms of the selected planting parameters satisfy the design requirement of soybean planting equipment. The fabricated 2 – row soybean planter has the best speed of operation of 0.83 m/s to achieve seeding rate of 24.72 kg/h, uniformity of spacing of 98.14 %, field efficiency of 78.05 % and less than 10 % seed damage to provide solutions to the major problems of time waste, seed losses, poor seeding, irregular intra spacing experienced by small scale farmers in Katsina state. The planter eliminates the unnecessary hard labour involved during planting operations using manual method of planting soybean. It was concluded that the fabricated 2 – row planter produced a precision planting of soybean on rows with low seed loss and performed effectively with planting efficiency of more than 75 % at optimum speed of operation of 0.83 m/s.

ACKNOWLEDGEMENT

This research work on design and fabrication was conducted with the assistance of technical contributors (Engr. Abdulganiyu Shehu and Engr. Abdulbasit Onife Isa), welding technician (Abdulaziz Usman) and field work assistance (Nuraddeen Isma'il). They are hereby fully acknowledged for their various contributions. The management of Federal College of Education, Katsina is highly acknowledged and appreciated for creating the opportunity for us through the TETFUND institutional base research committee of the college to undertake such a practically oriented research work. Also, all members of the College TETFUND IBR Committee are acknowledged for their various efforts at different levels to make this research possible. We sincerely acknowledged and appreciate the financial support of the TETFUND academic research development programme in the college. All financial implications of this research work were fully sponsored by TETFUND; with utmost gratitude we acknowledge and appreciate this gesture.

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REFERENCES

Adekanye, T. A., Alhassan, E. A., Okunola, A. A., Akande, D. I., Christina, O. W., Isaac, B. F. & Adeniyi, O. (2019). Evaluation of a Locust bean Seed Dehauling Machine for Small Scale Farmers, *International Journal of mechanical Engineering and technology (IJMET)*, 10(3): 273 – 283

Alfred, M. K. (2015). Design and Operation of a Seed Drill, Agricultural Machinery Conference Paper, accessed from *http://www.researchgate.net/publication*

Alhassan, E. A., Adejoke, D. A. & Bernard, O. (2018). Development of a Self Propelled Multi Crop Two-row Precision Planter: A New Design Concept for the Metering Mechanism, *International Journal of Mechanical Engineering and Technology (ICONSEET)*, 2(11): 78 – 86

American Society of Agricultural Engineers (2005).Standard Book, ASAE S224.1 Publication, USA, pp 70 -79

Dugje, I.Y., Ekelene, F., Omooigui L. & Ranajit, B. (2009). Farmer's Guide to Soybean Production in Northern Nigeria, *Training manual*, International Institute of Tropical Agriculture (IITA), Ibadan Nigeria.

FAO (Food and Agricultural Organisation) (1994). Testing and Evaluation of Agricultural Machinery and Equipment: Principles and practice; FAO *Agricultural Services Bulletin* 110:150 – 169.

Gambari, A.B., Bello, K.I, & Soyemi, Y.W. (2017). Development and Performance Evaluation of a Manually Operated Two-row Maize Planter. *International Conference of Science, Engineering and Environmental Technology (ICONSEET)*, 2(11):78 – 86.

Gbabo, A., Andrew, I. & Simeon, M.I. (2017). Design, Fabrication and Testing of a Tractor Drawn Soybean Planter. *FUW trend in Science and Technology Journal (FTST)*, 2(1B):562 – 568.

Jadhao, K. K., Avdhoot, S. N., Pavan, U. S., Vishal, N. A. & Akshay S. D. (2019). Mechanization of Manually Operated Seed Sowing Machine for Small Farming Land, *International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)*, 6(5): 35 – 38.

John, E. & Igwe, J. (2014). Development and Performance Evaluation of Manually Operated Cowpeas Precision Planter, *International Journal of Engineering and Technology (IJET)*, 4(12): 693 – 699

Kepner, R.A., Bainer, R. & Berger, E.L. (1978). *Principles of farm machinery*. 3rdEdition, West Port G; AVI Publishing Company Inc. Madison, USA, pp 209 –233.

Khurmi, R. S & Gupta, J. K (2005). *Machine design*, Eurasia Publishing House (Pvt) Ltd. Ram Nagar, New Delhi, India, 509 – 557.

Kumar, D. (2018). Studies on Performance Evaluation of Manually Operated Seed-Cum Fertilizer Soybean Planter, Unpublished *Ph.D Thesis* Submitted to Vaugh Institute of Agricultural Engineering and Technology, Sam Hagginbottom University of Agriculture, Technology and Sciences, Allahabad, India.

Moymoykimkim27, (2017). Methods of Planting, accessed from *http://www.slideshare.net/pulications*

Article DOI: 10.52589/AJAFS-EMS24XWI
DOI URL: https://doi.org/10.52589/AJAFS-EMS24XWI

Murray, J. R, Tullberg, J. N & Basnet, B. B. (2006). Planters and their components: Types, attributes, functional requirements, classification and description. *Austrlian Center of International Agricultural Research,* Camberra, ACIAR monograph 121.

Narengra, K., Sigh, M. K., Garg, S. K., & Verma, P. (2012). Performance Evaluation of Mechanical Planter for Planting of Chicken pea and Pigeon pea, *Journal of Food Legumes,* 25(2): 131 - 134

Oduma, O., Edeh J. C., & Onu, O. (2014). Performance Evaluation of a locally developed three-row maize planter. *International Journal of Agricultural science and Bioresource Engineering Research,* 3(4): 10.

Soyoye, B.O., Ademosun, O. C. & Agbetoye, L. A. S. (2018), Determination of some Physical and Mechanical Properties of Soybean and Maize in Relation to Planter Design. *Agricultural Engineering International CIGR Journal,* 20 (1), 81 – 89.

Spotts, M. F. (1988). *Design of machine element,* 6th Edition. Prentice – Hall of India private Ltd, New Delhi, 149 – 160

Srivastava, A. K, Carrol E. G, Roger P. R & Dennis R. B (2006), *Engineering Principles of Agricultural Machines*, 2nd edition, American Society of Agricultural and Bioresource Engineers (ASABE), USA.

Swapnil, T., Madhu, L. K., Patil, G. & Patil, R. (2017). Design and Fabrication of Seed Sowing Machine, *International Research Journal of Engineering and Technology (IRJET),* 4(09): 104 – 107.

Upahi, E. J. (2009). Development and Performance Optimization of a Two-row Engine Propelled Seed-Ridge Planter, Unpublished *Ph.D thesis* Submitted to the School of Post Graduate Studies, Ahmadu Bello University, Zaria

Yokesh, P. (1998). *Sowing and its Equipment.* Agricultural Engineering 243 Lecture 13, accessed from *http://www.academia.edu*

Yinusa, B. & Ajav, A. (2015). Determination of Shear Forces, Reactions and Bending Moments on the Driving Shaft of a Parallel Thrown Forage Dropper. *European Journal of Mechanical Engineering Research,* 2 (1): 14 – 21

Article DOI: 10.52589/AJAFS-EMS24XWI
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