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Development and Performance Evaluation of a Maize Planter

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Abstract- To meet the needs and reduce the difficulties of maize farming for rural, small, and medium-sized farmers, a self-propelled maize seeding machine has been produced with locally available materials. The major components of the machine are hopper, reducing gear, pillow bearing, gasoline engine, metering device, furrow opener, furrow closer, shafts, frame support, pulley, belt, casing, side cover, wheels, and handle. The machine was driven by a petrol engine and the power transmission from the reduction gear to the driving shaft that connects the front wheels with the aid of the sprocket and chain to shift the power from the front wheel to the metering mechanism by belt and pulley arrangement. At an average planting depth ranging from 2.47 cm to 2.60 cm, the planter effectively weighed three seeds per discharge, with an average seed damage of 8.33 percent. An average seed weight ranging from 4.44 g to 4.72 g was also collected from the hopper at a mean planting space range of 48.20 cm to 49.80 cm. 73.7 percent of field efficiency, 87.66 percent of machine efficiency and 0.30 ha/hr of average field power were obtained. The machine's manufacturing cost is $150.

Keywords Development, seed damage, field efficiency, field capacity, maize planter.

1. Introduction

Maize (Zea. mays L.) is a widely grown crop with a high percentage of photosynthesis response due to its process, which results in yield enhancement and potential for biomass. It is primarily cross-pollinated species, an attribute which has contributed to its wide morphological diversity and geographic adaptability. Since its costs of food, feed, and industrial use, it has acquired greater importance. There is worldwide cultivation of maize along wheat and rice. The Food and Agriculture Organization (FAO) forecasts yet another 60 million tons of maize grain from the annual global harvest would be required by 2030. The production as an animal feed will continue to rise faster than the demand for it as a human food, especially in Asia where demand is anticipated to double from the present level of 165 million tons to nearly 400 million tons by 2030[1]. There is many planting equipment available, both manual and animal-drawn. However, manual planters have a low work rate apart from the tremendous effort that is required to operate them in the field. In the case of animal-drawn planters, they are mostly single row with an equally low work rate. Also, they are complex, costly, lack spare parts, and under-utilized the power of the draught animal. In large mechanized farms, the use of tractors drawn planters are already in existence, but this method of planting is above the reach of the financial capacity of the peasant farmers that constituted. 90 percent of the farming population in Nigeria. Research indicates that the majority of growers could boost their yields by simply improving the output of the planter [2]. The main factors leading to low maize yield include the use of low yielding varieties and improper cultural management practices particularly in the area of fertilization, insects, diseases, weed control, and, most crucially, planting activity. Maize is commonly grown manually in Nigeria, and seed sown per hill is more than just the prescribed maximum during manual planting. Owing to the build-up of insects and nutrients and competition from sunshine, this results in overpopulation and gradually reduces yields. This maize cultivation method also involves a great deal of labor and time. Farmers perform maize sowing, which costs less but also less final revenue, due to increased plant population, higher seed costs, higher intercultural operational costs, and lower grain yields. With higher labor costs, few farmers practice labor-intensive line sowing methods, which also facilitates the adoption of maize planters. Different researchers were involved in the production and evaluation of planters for maize establishments [3-5]. In order to meet the needs and alleviate the difficulties faced by rural, small and medium-sized farmers in maize farming, a three-row manually operated maize seeding system [6] with locally available materials was developed. 'Reference [7]' suggested that use of the well-designed plant attachments to power tillers (two-wheel tractors) could produce more maize, wheat, pulses and oils for cultivation. Maize seeding operations in Nigeria are limited, as farmers still use bare hands or hand tools in the furrow beds to sow seed and then cover the seed by hand. On the market, maize planters are imported and designed to operate on large fields that are expensive and not suitable for local conditions. Thus, the use of large maize planters is not economically feasible under the conditions of Nigeria. A low-cost maize planter can remove all these constraints and is suitable for the establishment of Nigerian maize. Consequently, the aims of this study were to develop a low-cost maize planter and evaluate the production of the planter in the context of Nigeria.

2. Materials and Methods

2.1. Machine Description and Working Principle

The maize planter consists of the hopper, reducing gear, pillow bearing, gasoline engine, metering device, furrow opener, furrow closer, shafts, frame support, pulley, belt, casing, side cover, wheels and handle. The front-wheel which is the biggest of the wheels are connected by a belt and pulley to a petrol engine mounted on the frame of the machine. The petrol engine powers the front wheel which in turn powers the shaft that drives the metering device through a chain and a sprocket. The engine is connected to reducing gear, which helps reduce the rpm of the engine and the speed of the wheels which in turn determine the rate at which the metering device meters the seed. The metering systems are hollow shaft in a very way that each semicircular point collects two seeds at a time from the hopper and delivers them steadily into the discharge tube which then drops the seed to an already opened soil by the furrow opener. The deposited seeds are then protected by the furrow covering the unit located at the rear end of the machine.

Fig. 2. Isometric view of the maize planter.

2.2. Design Considerations

Simplicity in design, construction, and operation; protection and light in weight; for secure and quick transport; easy to operate and low maintenance; components and parts can be quickly dismantled for replacement of parts; use of locally available materials; right seed-box or feed hopper for carrying the seed and feeding the metering device; control of feed the metering device.

S/N	Components
1	Handle
2	Pulley
3	Belt
4	Casing
5	Side cover
6	Hopper
7	Reduction gear
8	Pillow bearing
9	Gasoline engine
10	Metering device
11	Furrow closer
12	Seed tube
13	Furrow opener
14	Shafts
15	Frame support
16	Wheels

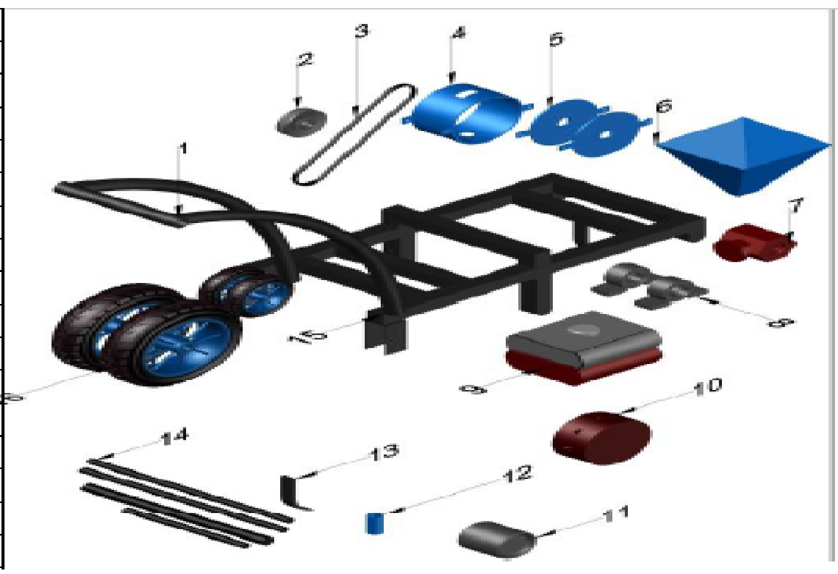

Fig. 1. The exploded view of a maize planter showing the major components.

2.3. Design Analysis

2.3.1. Determination of the mass of mainframe

The mass of the mainframe was determined using equations 1 to 4 as reported by [8].

$$L = [3(L1) + 2(L2) + 2(L3) + L1] \quad (1)$$

L is the total length of a planter mainframe, L1 is the planter frame width, L2 is the planter frame length and L3 is the height of the frame that supports handle. Substituting L1 = 300 mm, L2 = 990 mm and L3 = 750 mm. Therefore, a total length of 4680 mm was used for the planter mainframe.

$$V_{mfm} = W_{mfm} \times T_{mfm} \times L \quad (2)$$

Where V_{mfm} is the volume of the hopper. W_{mfm} is the width of the mainframe material, T_{mfm} is the thickness of the mainframe material, L is the total length of a planter mainframe. Substituting W_{mfm} = 20 mm, T_{mfm} = 2 mm and L = 4680 mm. Therefore, a total volume of 0.1872 m³ was used for the hopper volume.

$$M_{mfm} = V_{mfm} \times \rho_{mfm} \quad (3)$$

Where M_{mfm} is the mass of the mainframe material, V_{mfm} is the hopper volume, ρ_{mfm} is the density of the mainframe material. Substituting V_{mfm} = 187.20 cm³, ρ_{mfm} = 7.874 g/cm³. The mass of 1.474 kg was used for the mass of the mainframe material.

$$Wg_{mfm} = M_{mfm} \times g \quad (4)$$

Where Wg_{mfm} is the weight of the mainframe material, M_{mfm} is the mass of the mainframe material T_{mfm} and g is the acceleration due to gravity. Substituting M_{mfm} = 1.474 kg and g = 9.81 m/s^2. Weight of 14.45 N was used for the weight of the mainframe material.

2.3.2. Mass of hopper

By [9], the mass of the hopper was calculated using equations 5 to 7.

$$V_h = \frac{1}{3[(A_{fb})\ x\ Ht]} - \frac{1}{3[(A_{tf})]} \times H_{tf} + V_c \quad (5)$$

Where V_h is the volume of hopper, Afb is the area of frustum base, Ht is the total height, Atf is the area of the truncated frustum, H_{tf} is the height of truncated frustum, and V_c is the volume of the cylinder. Substituting A_{fb} = 34225 mm, H_t = 277 mm, A_{tf} = 31420 mm, H_{tf} = 32mm and V_c = 1005440 mm. Therefore, the volume of 3830.40 cm³ was used for the hopper volume.

$$M_h = V_h + \rho_h \quad (6)$$

Where M_h is the mass of hopper, V_h is the volume of hopper, ρ_h is the density of hopper. Substituting V_h = 3830.4 cm³ and ρ_h = 0.721 g/cm³. Mass of 2.7617 kg was used for the hopper mass.

$$W_h = M_h \times g \quad (7)$$

Where W_h is the weight of hopper, M_h is the mass of hopper and g is the acceleration due to gravity. Substituting M_h = 2.7617 kg and g = 9.81 $m/s2$. Hopper weight of 27.09 N was used.

2.3.3. Mass of metering device casing

The mass of metering device casing was calculated using equations 8 to 10 as reported by [8].

$$V_{mdc} = \pi \times R_{mdc}{}^2 \times W_{mdc} \times t \times [2\pi R_{plates}{}^2 - 2\pi R_{shafts\ hole}{}^2 \times t + \pi R_{pipe\ under}{}^2 \times H_{pipe\ under} \quad (8)$$

V_{mdc} is the volume of the metering device casing, R_{mdc} is the radius of the metering device casing, W_{mdc} is the width of the metering device casing, t is the thickness of the material, R_{plates} is the radius of the plates metering device casing, $R_{shafts\ hole}$ is the radius of the shaft hole on the plates, $R_{pipe\ under}$ is the radius of the pipe under the casing and $H_{pipe\ under}$ is the height of the pipe under the casing. Substituting R_{mdc} = 100 mm, W_{mdc} = 37 mm, t = 2 mm, R_{plates} = 100 mm, $R_{shafts\ hole}$ = 12 mm, $R_{pipe\ under}$ = 10 mm and $H_{pipe\ under}$ = 32 mm. The volume of the metering device casing of 2459 cm³ was used.

$$M_{mdc} = V_{mdc} \times \rho_{mdc} \quad (9)$$

Where M_{mdc} is mass of the metering device casing, V_{mdc} is the volume of the metering device casing and ρ_{mdc} is the density of the metering device casing. Substituting V_{mdc} = 2459 cm³ and ρ_{mdc} = 7.85g/cm³. Therefore, the mass of the metering device casing of 19.3 kg was used.

$$W_{mdc} = M_{mdc} \times g \quad (10)$$

W_{mdc} is the weight of the metering device casing, M_{mdc} is mass of the metering device casing and g is the acceleration due to gravity. Substituting M_{mdc} = 19.30 kg and g = 9.81 m/s^2. Weight of the metering device casing of 189.3 N was used.

2.3.4. Design of the metering device

2.3.4.1. Mass of metering device

The mass of the measuring device was determined using equations 11 to 13 as reported by [9].

$$V_{md} = \pi\,[R_{md}{}^2 - R_{shafts\ hole}{}^2] \times T_{md} \quad (11)$$

Where V_{md} is the volume of the metering device, R_{md} is the radius of the metering device, $R_{shafts\ hole}$ is the radius of the shaft hole and T_{md} is the thickness of the metering device. Substituting R_{md} = 98 mm, $R_{shafts\ hole}$ = 0.60 mm and T_{md} = 35 mm. volume of the metering device of 1056.11 cm³ was used.

$$M_{md} = V_{md} \times \rho_{md} \quad (12)$$

Where M_{md} is mass of the metering device, V_{md} is the volume of the metering device and ρ_{md} is the density of the metering device. Substituting V_{md} = 1056.11 cm³ and ρ_{md} = 0.6 g/cm³. Mass of metering device of 0.633 kg was used.

$$W_{md} = M_{md} \times g \quad (13)$$

Where W_{md} is the weight of the metering device, M_{md} is mass of the metering device and g is acceleration due to gravity. Substituting M_{md} = 0.633 kg and g = 9.81 m/s^2. Weight of the metering device of 6.21 N was used.

2.3.4.2. Calibration of metering device

The metering device was designed using equations 14 and 15 as reported by [10].

$$N_c C = \frac{\pi D_w N_w}{S} \quad (14)$$

Where N_c is the number of revolutions of the cell, C number of cells, D_w is the diameter of the wheel, N_w is number of revolutions of wheel and S is ground spacing.

$$N_w = N_c = n(number\ of\ revolution) \quad (15)$$

Since the shaft is on the wheel and the seed plate. Therefore, the wheel and the seed plate will rotate at the same number of revolutions (n). Substituting π = 3.142, D_w= 38 cm and S = 35 cm. Therefore, the number of cells used was 3.

2.3.5. Design of pulley

The velocity ratio of the pulley and belt of the rotating shaft was calculated using equation 16 as presented by [9].

$$N_1 D_1 = N_2 D_2 \quad (16)$$

Where N_1 is driver speed, $D1$ is the driver pulley diameter, N_2 is the shaft speed and D_2 is the shaft pulley diameter. Substituting $N1$= 1800 rpm, D_2 = 120 mm, D_1 = 70 mm. Therefore, the speed of the shaft of 1050 rpm was used.

2.3.6. Design of the speed of belt

The planter belt speed was determined using equation 17 as reported by [8].

$$V = \pi D N_1/60 \quad (17)$$

Where V is planter belt speed, D is the difference in the diameter of the shaft pulley and the diameter of the driver pulley and $N1$ is speed of the driver. Substituting D = 0.050 m and N_1 = 1800 rpm. Therefore, a planter belt speed of 4.7 m/s was used.

2.3.7. Shaft Diameter

The shaft diameter of the planter was calculated via equation 18 as stated by [9].

$$d^3 = \frac{16}{\pi_{sa}}\sqrt{(K_b M_b)^2 + (K_t M_t)^2} \quad (18)$$

Where d is the diameter of the shaft, S_a is allowable stress, K_b is combined shock and fatigue factor applied to bending moment, M_b is bending moment, K_t is combined shock and fatigue factor applied to torsional moment and M_t is a torsional moment. Substituting S_a = 40 MNm^{-2} M N/m^2, K_b = 1.50, M_b = 55.81 Nm, K_t = 1.50 and M_t = 114 Nm. Factor of safety = 1.50. Therefore, a shaft diameter of 26 mm was used.

2.3.8. Determination of Power Required for the Planter

The total power required for the planter was determined using equations 19 and 20 as reported by [8].

2.3.8.1. Determination of power required to push the wheel of the planter

$$P_1 = M_t 2\pi N \quad (19)$$

Where P_1 is the power required to push the wheel, M_t is the torsional moment and N is the rotating speed. Substituting M_t = 114 Nm and N = 1 rpm. Power of 715.92 W would be required to push the wheel.

2.3.8.2. Determination of power required to roll the metering device of the planter

$$P_2 = \tau \times \omega \quad (20)$$

Where P_2 is total power for operating the machine, N = speed (rpm) τ= force × radius of the wheel = 300.83 × 380mm = 114 N mm Substituting τ = 114 N mm and ω = 2π = 6.28 rad/sec. Therefore, power of 24.96 W would be required to roll the metering device of the planter. Total power required to push the machine P = 715.92 + 24.96 = 740.88W. Factor of safety = 1.50. Therefore, the total power required to push the machine would be 1111.32 W.

2.4. Material Selection

The chosen materials should be appropriate for the machine's working and service conditions. Material choice must be such that it can be shaped into the desired shape, based on the metal's ductility characteristics. Metal forming is usually done by working cold, which means forming at room temperature. Factors that contribute to the choice of materials for the machine's development include corrosion resistance, friction coefficient, commercial quality, material costs, ease of maintenance, manufacturing facility, manufacturing techniques, mechanical properties and surface corrosion resistance, creeping strength, tiredness. Table 1 shows the chosen components used to explain the choice of which were the best and most appropriate material from the available options.

S/N	Component	Description	Cost ($)
1	Handle	Angle iron of 30.2 mm x 30.2 mm x 3 mm dimension was selected. Mainframe of length 900 mm was used	10.00
2	Pulley	40 mm and 120 mm	10.00
3	Belt	Rubber	1.00
4	Casing	Aluminum	2.50
5	Side cover	Aluminum	3.00
6	Hopper	Mild steel sheet metal of 3 mm thickness was used	5.00
7	Reduction gear	Cast iron	12.50
8	Pillow bearing	26 mm diameter	1.50
9	Gasoline Engine	2.0 hp	40.00
10	Seed metering mechanism	Aluminum of 210 mm diameter and 20 mm thickness with three equally spaced cells near	10.00
11	Furrow closer	Mild steel angle iron of 2 mm thickness	5.00
12	Seed tube	A cylindrical funnel made of mild steel pipe with a diameter of 32 mm.	3.00
13	Furrow opener	Mild steel angle iron of 2 mm thickness	3.00
14	Shaft	Mild steel of 26 mm diameter	6.50
15	Front-wheel	Driven wheel made of rigid rubber wheel of 380 mm diameter	7.50
16	The rear wheel	It has a diameter of 95 mm attached to a roller	7.50
17	Frame support	Mild steel	5.00
18	Wheel	The front rubber wheel of 380 mm diameter and rear rubber wheel of 95 mm diameter were used.	15.00
19	Bolts and nuts	The dimension of 15 mm by 17 mm were used	2.00
	Total		150.00

2.5. Planting Operation

The front-wheel which is the biggest of the wheels is connected by a belt and pulley to a petrol engine mounted on the frame of the machine. The petrol engine power the front wheel which in turn powers the shaft that drives the metering device through a chain and a sprocket. The engine is connected to reducing gear, which helps in reducing the speed of the engine and the speed of the wheels which in turn determine the rate at which the metering device meters the seed. The metering mechanisms are castellated in a very way that each castellated point collects two seeds from the hopper at even a time and continually introduces them into the discharge tube, which then deposits the seed through the furrow opener in the already opened soil. Then the furrow covering the unit situated at the rear end of the machine covers the deposited seeds.

2.6. Check for Results

The Department of Crop Science and Development of the Federal University of Technology Akure obtained a local maize variety called Agric yellow, popularly cultivated by local farmers. As calculated by the oven-dry method of moisture content calculation, the seed moisture content of 13.06 percent was used. The output of the machine was assessed using the standard seed drill code as reported by [11].

2.7. Test of the Laboratory

The system was adjusted in the laboratory to determine the discharge rate, uniformity of seed spacing, and seed damage during service.

2.8. Test Calibration

The hopper of the planter was filled with 2 kg of maize seeds, the petrol engine was turned on and the drive wheels were pushed. On the wheels, a label was made to show the reference points to count the number of revolutions when rotated, and a sac was placed on each of the seed tubes to collect the discharged seeds. As would be obtained on the ground, the wheels could rotate at low speed (1 m/s) for 20 seconds. A stopwatch for calculating the time taken to complete the revolutions was used. Weighed on the balance the seeds gathered in the sacs, and repeated the process ten times.

2.9. Seed Spacing Uniformity

Using the standard procedure, the uniformity of seed spacing was calculated. A seed weighing 2 kg was loaded into the hopper. 20 m was marked out on the plain ground at a speed of 1 m / s, and the machine runs within the range, and the travel time has been registered. To measure the distance between successive drops of seeds, a measuring tape was used. This process was repeated five times and the distance measurement was taken and recorded between successive drops of seeds.

2.10. Seed Damage Test

The planter was stocked, and 2 kg of seeds were put in each hopper. The wheels were rotated 30 times, and the stopwatch was used to track the time taken for the revolution to complete. The seeds discharged from the seed tubes were observed for damage and recorded.

2.11. Field Test and Performance Evaluation Parameters

For the evaluation, an area of 100 x 100 m was used. In order to provide reasonable soil conditions for the crop and a workable area for the planter, the field was correctly ploughed and harrowed. Field effectiveness, field capacity, planting depth, and seed spacing uniformity were calculated.

2.11.1. Productivity on the field

The efficiency of the field was measured using the suggested equation 21[12]. The planting operation was conducted longitudinally with a constant forward speed while determining the field efficiency of the planter, as calculated by noting the travel distance using a measuring tape and the corresponding time to complete the distance using a stopwatch while planting the prepared field area. Efficient running time and time spent on hopper filling, stump removal and other obstructions [13].

$$\mathcal{E} = \frac{100T_e}{T_t} \tag{21}$$

Where, Ɛ is field efficiency (%), T_e is effective operating time (min) and Tt total time (min)

2.11.2. Effective field capacity

Equation 22 was used to test the effective field potential as recommended by [12]. The effective field capacity was determined by measuring with a measuring tape the effective width of the planter and the forward constant velocity of the planting process.

$$Ce = \frac{W_s}{100} \times \mathcal{E} \tag{22}$$

2.11.3. Depth of Planting

Using the standard method recommended by [11], the mean planting depth of the seeds was calculated. It was done by running the planter to and from over an area of 10 square meters without the furrow covering tool and with the medium setting of the furrow opener. During the process, the time taken to shift the field length was calculated to determine the average field operating speed. Fifteen holes in each furrow were randomly sampled and examined for planting depth. A measuring tape was used for the calculation of the required depth.

2.11.4. Uniformity Seed Spacing

The evenness of seed spacing was computed after seed germination. This was completed 2 weeks after planting. The distance between successive seedlings within the row was measured for the whole area planted using a measuring tape. During performance tests, both organizational and change problems were found and corrected.

3. Results and Discussion

The results obtained from performance evaluation showed that with a planting capacity of 0.0486 hectares / hr, the planter performed well as anticipated. Visual inspection of the seeds released from the metering system of the planter showed no noticeable evidence of the seeds being harmed. At an average planting depth ranging from 2.47 cm to 2.60 cm with an average seed harm of 8.33 percent, the planter effectively counted four seeds per discharge. The assessment obtained a field efficiency of 73.7 percent, a system efficiency of 87.66 percent and an average field output of 0.30 ha / hr. The machine efficiency (87.66%) was higher than that of other researchers (ranges from 70-72%). The other results obtained were in agreement with the findings other researchers who discovered that the developed planters can plant two seeds per discharge, planting depth ranges from 2.47-4.50 cm, field efficiency ranges from 71.86-91% and field capacity ranges from 0.10-0.50 ha/hr respectively [6, 14].

4. Conclusion

A manually operated single-row maize planter was designed, constructed, and tested for planting maize. The planter for maize is inexpensive, easy to afford, easy to maintain, and less laborious to use. The planter has a planting capacity of 0.0486 hectares / hr, effectively measuring four seeds per discharge at an average planting depth ranging from 2.47 to 2.60 cm with an average seed harm of 8.33 percent, a field efficiency of 73.7 percent, a system efficiency of 87.66 percent and an average field capacity of 0.30 ha / hr with a production cost of USD 150. The planter is compact, easy to operate and easy to maintain and can, if properly managed, mitigate the difficulties faced by maize farmers in rural areas. The planting company would go a long way in making farming more attractive and growing agricultural production.

APPENDIX

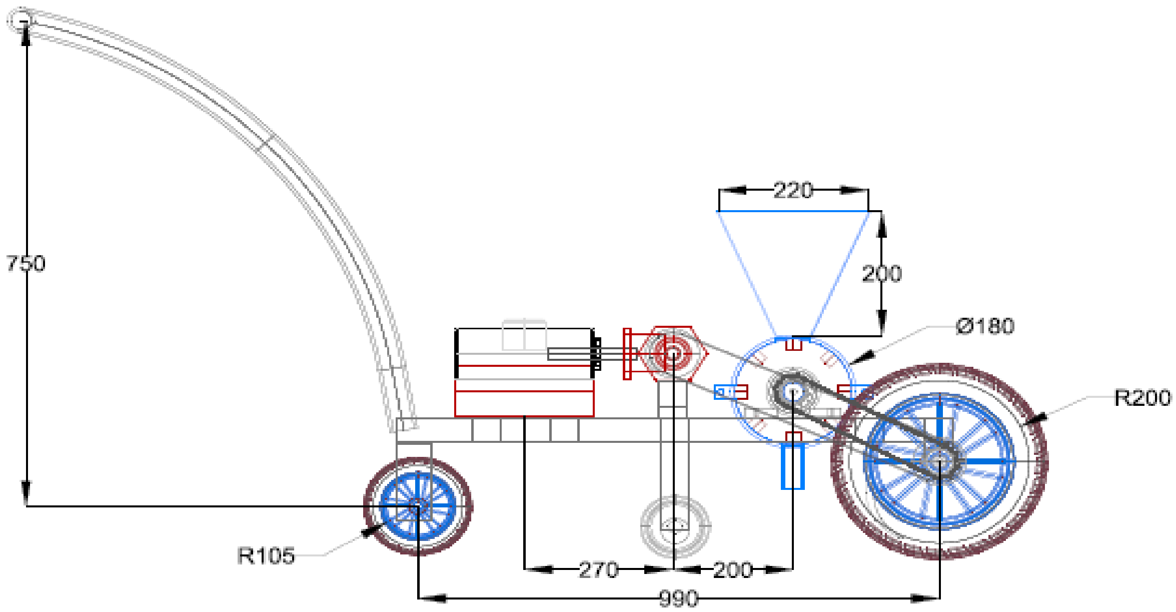

Fig. 3. The side view of a cowpea planter.

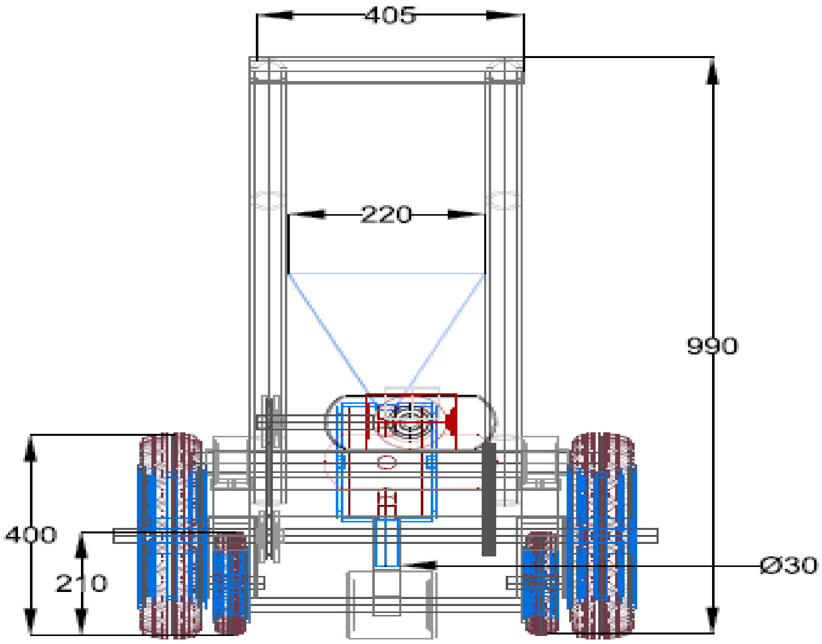

Fig. 4. The front view of a cowpea planter.

References

[1] R. L. Paliwal, G. Granados, H. R. Lafitte, A. D. Violic, and J. P. Marathée, Tropical Maize: Improvement and Production. FAO Plant Production and Protection Series. Volume 28. FAO, Rome, Italy, 2000

[2] J. R. N. Murray, J. Tullberg and B. B. Basnet, Australian Center for International Agricultural Research (ACIAR) Monograph 121, 2006

[3] S. Singh, Design, Development, And Evaluation of Tractor-Drawn Ridger Planter for Winter Maize. Biennial Report, Department of Farm Power and Machinery, PAU, Ludhiana, India, 1984

[4] L. O. Adekoya and W. F. Buchele, “A Precision Punch Planter for Use in Titled and Untitled Soil”, Journal of Agric-Engineering research, vol. 37, issue 3, pp. 172-178, 1987

[5] A. Lara-Lopez, J. Guillen-Sanchez, and L. Perez-Sobrenlla, “Development of A Direct Planter for Corn and Faba Beans”, Agricultural Mechanization in Asia, Africa and Latin America, vol. 27, issue 2, pp. 25-28, 1996

[6] O. Oduma, J. C. Ede, and J. E. Igwe, “Development and Performance Evaluation of a Manually Operated Cowpea Precision Planter”, International Journal of Engineering and Technology, vol. 4, issue 12, pp. 4-7, 2014

[7] S. Ahmmed, K. C. Roy, M. N. M. A. Amin, Wohab, and M. A. Matin, “Design and Development of a Power Tiller Operated Inclined Plate Multi-crop Planter”, Journal of the Institutions of Engineers Bangladesh, Agril. Eng. Division 31/AE, vol. 1, pp. 89-96, 2004

[8] R. S. Khurmi, and J. K. Gupta, Theory of Machines, Eurasia Publishing House (PVT) Ltd. New Delhi, 8th Edition, 2007, pp. 72-81

[9] R. S. Khurmi, and J. K. Gupta, A textbook of machine design, 14th edition, New Delhi: Eurasia Publishing House (PVT) Ltd., 2008, pp. 79-89

[10] M. A. Rabbani, M. M. Hossain, J. F. Asha, and N. A. Khan, “Design and Development of a Low-cost Planter for Maize Establishment”, Journal of Science, Technology and Environment Informatics, vol. 4, issue 1, pp. 270-279, 2016

[11] I. Bamgboye, and A. S. Mofolasayo, “Performance Evaluation of a Two-row Okra Plant” Agricultural Engineering International, The CIGR E-Journal. Manuscript PM 06 002. vol. 8, 2006

[12] R. A. Kepner, R.Bainer, and E. L. Benger, Principles of Farm Machinery. 3rd Edition.Westport. G. AV, Publishing company Inc. 1978.

[13] S. Afzalinia, M. Shaker, and Z. Zare, “Performance Evaluation of Common Drills in Iran”, Canadian Bio-system engineering/ Le genie des Biosystem es au Canada, vol. 48, issue 2, pp.39- 43, 2006

[14] A. Elijah, and D. A. Adejoke, “Development of a Self-propelled Multi-crop Two Rows Precision Planter”, A New Design Concept for The Metering Mechanism. International Journal of Mechanical Engineering and Technology, vol. 9, issue10, pp. 349 – 358, 2018