

DEVELOPMENT OF A MANUALLY OPERATED TWO ROW-SINGLE METERING PLATE MAIZE PLANTER

A. J. Abubakar*, S. A. Iya, H. U. Kabri and B. Garba

Department of Agricultural and Environmental Engineering, Modibbo Adama University of Technology, Yola.

*Corresponding author: abubakarjilima@mautech.edu.ng

ABSTRACT

Maize planting is a very tedious operation which is mostly done manually in Nigeria making it expensive and less efficient. This research work develops a manually operated two row maize planter with single horizontal plate metering mechanism, constructed using locally available material (mild steel Square pipe, circular rod and sheets) to make it affordable to the local farmers and carried out its performance evaluation in order to reduce the drudgery involve in manual maize planting as well as improve the timeliness of the operation. The planter consists of the following parts: the main frame, a feeding hopper, a horizontal disc metering mechanism, two land wheels, bevel gears and a push handle. The performance of the planter was carried out using maize seeds. The result of the performance of the planter include an average field efficiency of 68.18%, a field capacity of 0.16 ha/h with an average of 13.3% seed damaged and an average missing rate of 17.5%. The average intra row spacing of the developed planter is 34.4 cm and a total plant population of 38,725 stands/ha. The developed maize planter can be operated efficiently by a single person and can be adopted for use by our local farmers.

Key words: manual, two row, maize planter, horizontal plate, metering mechanism

1 INTRODUCTION

Maize is the third most important grain crop in the world constituting a major staple food for large number of people in many regions of the world, it also constitutes about sixty percent by weight of most livestock feed formulation [1] as well it serves as a raw material for industrial products such as maize sweeteners, maize oil and maize syrup. Other maize products include sealing brand, gypsum wall, warmish, spark plugs, adhesives, toothpaste, aspirin, diapers and coated paper products [2, 3]. Livestock sector in Nigeria is growing as more people are going in to poultry and fish production resulting in more demand for maize for feed formulation. Nigeria has the potentials of producing more of the crop as Maize performs very well in almost every part of the country from the north to the south. Karima [4] reported that the annual demand of maize in Nigeria stands at about 12.5 million tons but in 2019, only 11 million tons of maize was produced in Nigeria while the balance was imported from neighbouring countries [5]. Maize production in Nigeria has been reported to be declining due to many factors among which include unstable price of the product and the drudgery involve in its production as many farmers rely on crude traditional methods and implements in carrying out critical field operations using hoes, cutlasses or dibbling sticks [6]. Planting with such implements is time consuming, tedious, back-breaking and expensive as most of the farmers depends mostly on the services of youth (labourers) in the farming communities for planting operation. In order to address these problems, several researchers have developed planting machines among which include a self-propelled multi-crop two rows precision planter developed by [7] mainly for planting *maize, cowpea, and soybean*. The field efficiency of the machine was 81.2% at a working speed of 8.25 km/hr with a field capacity of 0.1 ha/hr. The metering mechanism use on this machine are two vertical plate metering device each one serving a single row. [8] also develops a manually operated two-row maize planter which uses two hoppers each with vertical disc seed metering mechanism. During the performance evaluation of the machine, the effective field capacities obtained are 0.180ha/hr, 0.131 ha/hr and 0.166ha/hr and the planting efficiencies were: 71 %, 82 % and 76 % at the forward speeds of 2.2 km/hr, 1.6 km/hr and 1.3 km/hr respectively. [9] developed a vertical plate maize planter for gardens and small holder farmers. The planter is a single row planter which uses a vertical plate seed metering mechanism,

during its performance evaluation a field efficiency of 71.86% was obtained at a field capacity of 0.27ha/hr and a metering efficiency of 88.94%. [10] designed, fabricated and tested a low-cost grain planter for planting maize, soybean and cowpea. The planter had 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. [11] also 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 hectare/hr. The main aim of this study is to develop and evaluated the performance of a two row Maize Planter.

2 MATERIALS AND METHOD

2.1 Design Considerations

This research focuses on producing a planter that will be cheap, light in weight and durable. To achieve this some factors were considered among which include: components parts easily dismountable for replacement and repairs, safety of operation, light in weight for safe transportation, ease of operation, low cost of maintenance, use of locally available materials, correct seed box or feed hopper to bear the seed and feed the metering device, control planting depth of 3 cm and spacing of 75cm by 25cm at one plant per stand and simplicity in design and construction making it reproducible by local artisan and ease of operation.

2.2 Design of individual components

The exploded and orthographic views of the designed machine is shown on Figures 1 and 2. The planter consists of the following components: a metering plate, hopper, bevel gear and pinion, seed tube, furrow opener, frame, land wheel, furrow closer, main shaft and handle each of which was designed independently as follows:

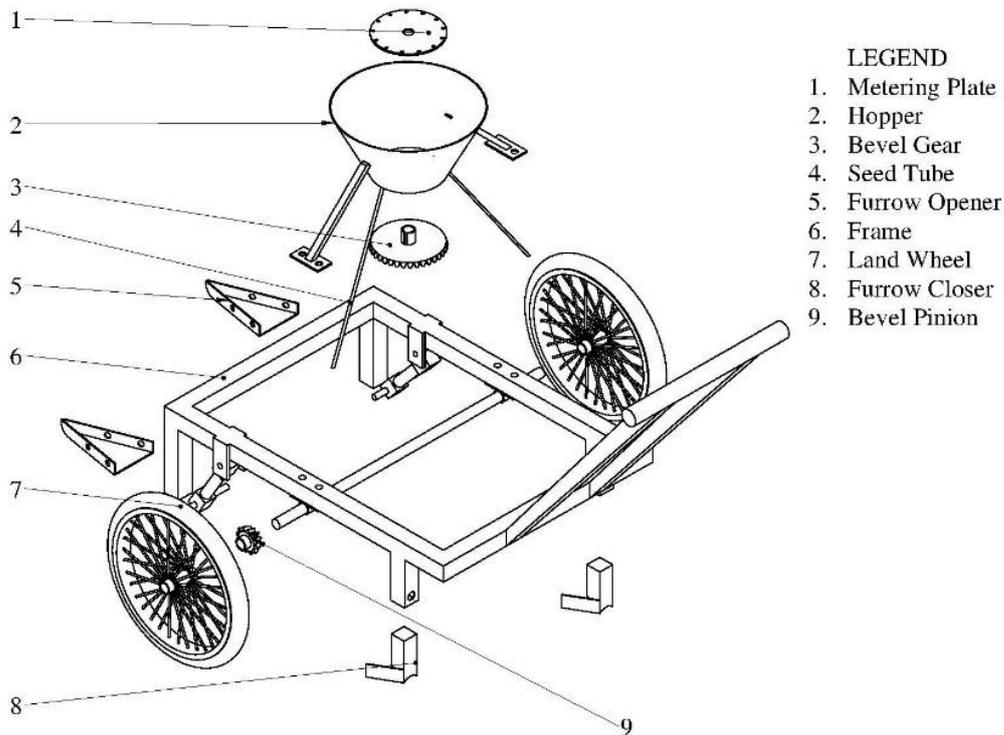


Figure 1. Exploded View of the Developed Two Row Maize Planter

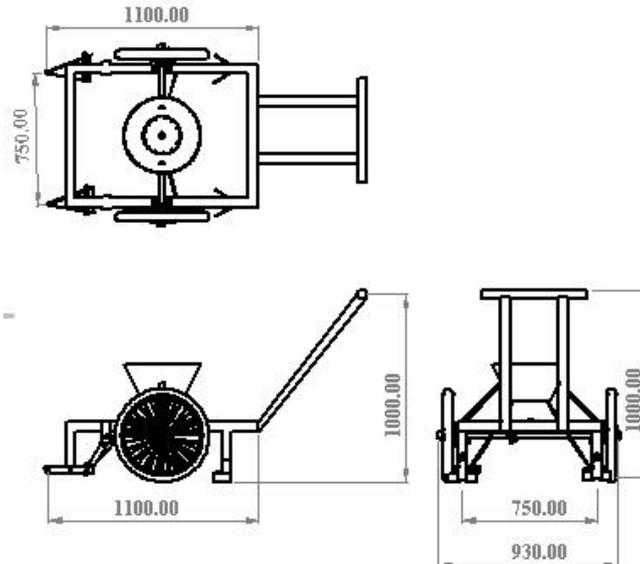


Figure 2. Orthographic View of the Developed Two Row Maize Planter

2.2.1 Design of Hopper

The hopper was designed using the following equations:

The volume of the hopper was calculated using Equation 1 [12]

$$V = \frac{\pi h}{3} [r_1^2 + r_2^2 + r_1 r_2] \quad (1)$$

Where: V is volume of the hopper (mm^3); h is height of the frustum (mm); r_1 is top radius of the frustum (mm); r_2 is bottom radius of the frustum (mm); The surface area, volume of material and mass of the hopper were calculated thus [12]:

$$A = \pi h(r_1 + r_2) + \pi r_2^2 \quad (2)$$

$$V = A \times t \quad (3)$$

$$M_h = V \times \rho \quad (4)$$

Where: A is total surface area of the Hopper (mm^2); h is height of the frustum (mm); r_1 is top radius of the frustum (mm); r_2 is bottom radius of the frustum (mm); V is the Volume of the Hopper material (mm^3); t is thickness of the material (mm); M_h is mass of the Hopper (kg); ρ is density of the hopper material (kg/m^3) = 7850 kg/m^3 .

2.2.2 Determination of the diameter of the land wheel

The diameter of the land wheel was determined using the following equations [12]:

$$D = \frac{P}{\pi} \quad (5)$$

Where: D is Diameter of land wheel (mm); P is linear distance covered by the land wheel per revolution (mm).

2.2.3 Design of gear drive mechanism

Bevel gear and pinion gear selected for this design are those having 12 and 36 numbers of teeth to transmit force from the land wheel to the metering mechanism. The gear ratio used on the planter is;

$$\frac{\text{Drivens}}{\text{Driving}} = \frac{36}{12} = \frac{3}{1} \rightarrow 3:1 \quad (6)$$

2.2.4 Design of the metering device

Metering device is the heart of sowing machine and its function is to distribute seeds uniformly at the desired application rate. In planters it also controls seed spacing in a row. A seed planter may be

required to drop the seeds at rates varying across wide range. Proper design of the metering device is an essential element for satisfactory performance of the seed planter (Sowing and planting).

The metering mechanism was design using the following equations [12]:

$$L = G_r \times P \quad (7)$$

Where: L is distance covered by the land wheel per revolution of the metering mechanism (mm); G_r is Gear ratio; P is Perimeter of the land wheel (mm).

- The diameter of the land wheel was determined using Equation 8 [12]

$$d = \frac{D}{G_r} \quad (8)$$

Where: d is diameter of metering plate (mm); D is diameter of land wheel (mm); G_r is gear ratio.

- The number of cells on metering plate was determined using Equation (9).

$$c = \frac{L}{2S} \quad (9)$$

Where: c is number of cells on the metering plate; L is distance covered by the land wheel per revolution of the land wheel (mm); S is intra row spacing between stands (mm). The designed horizontal disc metering plate is shown on Figure 3.

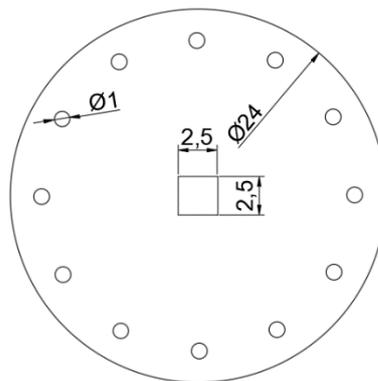


Figure 3. Plan View of the Designed Horizontal Disc Metering plate

2.2.5 Shaft Design

The design of shaft consists primarily of the determination of the correct diameter to ensure satisfactory strength and rigidity when the shaft is transmitting power under various operating and loading conditions. Shaft is usually circular in cross-sections and may be either hollow or solid. For shaft design, the bending moment and twisting moments of the load acting on the shaft were determined and the following formulas used to get the optimum diameter of the shaft [13, 14].

$$d^3 = \frac{16}{\pi\tau_{max}} [(K_b M_b)^2 + (K_t M_t)^2]^{\frac{1}{2}} \quad (10)$$

Where: d is diameter of the shaft (m); τ_{max} is allowable stress (MN/m²); M_b is Bending moment (Nm); M_t is torsional moment (Nm); K_b is combine shock and fatigue factor applied to bending moment; K_t is combine shock and fatigue factor applied to torsional moment. For rotating shafts, when load is suddenly applied (minor shock): $K_b = 1.5$ to 2.0 ; $K_t = 1.0$ to 1.5 . The bending moments (M_b) is determined using Equation 11.

$$M_b = (M_v^2 + M_h^2)^{\frac{1}{2}} \quad 11$$

Where: M_v is vertical bending moment (Nm); M_h is horizontal bending moment (Nm). The torsional moments (M_t) is determined using Equation 12.

$$M_t = \frac{9550 \times P}{n} \quad (12)$$

Where: P is power transmitted by shaft (kW); n is angular speed (rpm).

2.2.6 Construction of the Machine

The construction of the planter was done part by part through the process of cutting, forming and welding and later assembled together using bolt and nut. The hopper was constructed with 3 mm thick metal sheet. The main frame was constructed with square pipe to provide the required strength and rigidity. The seed plate was constructed with 3mm thickness metal sheet. The hopper and handle were fastened to the main frame with bolt and nut to enable easy detachment of the various component parts of the planter.

2.2.7 Mode of Operation of the Planter

The major aim of the maize planter is to place 1 to 2 seeds of maize at the depth of 2.5 – 3.5 cm at an inter-row spacing of 60 -75 cm and an intra-row spacing of 25 – 30 cm to obtain a well establish maize farm [9]. The developed planter as show on Figure 4 is designed to be pushed, as the machine is pushed a furrow opener (3) located in the front of the machines opens a continuous furrow, as well power is transmitted from the land wheel (4) through a set of bevel gears (7) to a horizontal disc metering device (not visible) located at the bottom of the hopper (1) having 12 holes and rotate at a speed equal to 1/3rd of the land wheel (4) delivering seed to 2 seed tube (6) for the 2 rows planted at the appropriate time given a spacing of 25 cm between the seeds and 75 cm between the rows. As the seeds are delivered to the furrow a furrow closing devices (5) located behind the seed tube pushes back the soil onto the placed seeds covering them with loose soil.

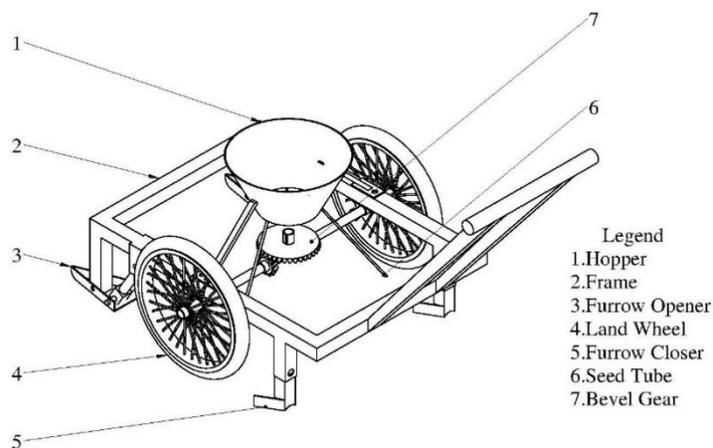


Figure 4. Isometric View of the Developed Two Row Maize Planter

2.2.8 Field Performance Evaluation

After constructing the machine, its performance evaluation was carried out on a 10 x 10 meter-square land with maize seeds. The land was first ploughed to obtain a good loose soil for the crop and workable environment for the planter. Planting exercise was carried out by putting 2 kg of good maize seeds in to the hopper and running the machine without a furrow closed over 50 m length of the land recording the time spent to cover the said distance using a stop watch to determine and observe the seeds distribution pattern along the rows. This was used in the calculation of some measurable parameters such as the number of seeds discharged or planted per hill, planting depth, missing rate, distance of dropped maize seed, percentage seed damage, effective field capacity and field efficiency.

2.2.8.1 Determination of number of seeds discharged per hill

The number of seeds dropped by the planter at every point along the 50 m furrow was counted.

2.2.8.2 Determination of missing rate

The distance between dropped seed was determined by measuring the distance of one group of seeds to the next group, if the distance is more than 25 -30 cm then missing occurs and a miss is recorded, and the missing rate was calculated using Equation 13 as reported by [14].

$$\text{Percentage missing rate} = \frac{N_1}{N_2} \times 100 \quad (13)$$

Where: N_1 is Number of missing hills; N_2 is Number of hills if missing occurs.

2.2.8.3 Determination of percentage seed damage

The seeds dropped were later observed and the number of damaged seeds were recorded, Equation 14 was then used to determine the percentage seed damaged.

$$\text{Percentage seed damaged} = \frac{n_1}{n_2} \times 100 \quad (14)$$

Where: n is Number of damaged seeds; n_2 is Total number of seeds discharged.

2.2.8.4 Theoretical field capacity

The theoretical field capacity was calculated using Equation 15 as reported by [9, 15]

$$C_{th} = w \times s \times \frac{3600}{10000} \quad (15)$$

Where: C_{th} is the theoretical field capacity (ha/h); w is the operating width of the planter (m) = 0.75 m; s is average speed of human in field operation (m/s) = 0.81m/s.

2.2.8.5 Effective field capacity

The effective field capacity was obtained using Equation 16 as reported by [16]

$$C_{eff} = \frac{A}{t} \times \frac{3600}{10000} \quad (16)$$

Where: C_{eff} is effective field capacity (ha/h); A is the area covered; t is the time taken.

2.2.8.6 Field efficiency

The field efficiency was calculated using Equation 17 as reported by [7]

$$E = \frac{C_{eff}}{C_{th}} \times 100 \quad (17)$$

Where: E is field efficiency; C_{eff} is effective field capacity; C_{th} is theoretical field capacity.

3 RESULTS AND DISCUSSION

The pictorial view of the developed two row single metering plate maize planter is shown on Plate 1.



Plate 1. Pictorial View of the Constructed Two Row Single Metering Plate Maize Planter

The result of the field performance evaluation of the developed maize planter among which include: missing rate, intra row spacing of hills, percentage seed damage, effective field capacity and field efficiency is presented on Table 1.

Table 1. Results of Field Performance Evaluation of the Developed Maize Planter

	Test 1		Test 2		Test 3	
	Row 1	Row 2	Row 1	Row 2	Row 1	Row 2
Intra row spacing (cm)	35.05	34.43	34.76	34.10	33.68	34.48
Missing rate (%)	19.05	14.29	14.29	19.05	14.29	23.81
Percentage seed damaged (%)	13.89	11.76	14.29	12.90	14.29	12.50
Effective field capacity (ha/h)	0.17		0.15		0.16	
Field Efficiency (%)	77.27		68.18		72.73	
Plant Population (stands/ha)	38,379		38,725		39,157	

The average distance between hills as shown on Table 1 ranges from 33.62 cm to 35.05 cm, for the first test the average spacing between hills is 35.05 cm for row 1 and 34.43 cm for row 2, while that of the second test is 34.76 cm and 34.1 cm for row 1 and row 2 respectively. The average spacing between hills was 33.62 cm and 34.48 cm for row 1 and row 2 respectively. The intra row spacing of the developed planter falls between that obtained by [14, 16]. The missing rate of the maize planter ranges between 14.19% and 23.81% which is close to that obtained [14]. During the first field test of the developed planter 4 hills representing 19.04% were missed on row 1 while 3 hills representing 14.28% were missed on row 2. During the second test 3 hills representing 14.28% were missed on row 1 while 4 hills representing 19.04% were missed on row 2, for the third test 3 hills representing 14.28% were missed on row 1 while 5 hills representing 23.81% were missed on row 2. The percentage of seed damaged by the planter ranges between 11.76% and 14.29% which is higher than that obtained by [7]. During the first test 5 seeds representing 13.89% were damaged on row 1 while 4 seeds representing 11.76% were damaged on row 2, during the second test 5 seeds representing 14.29% were damage on row 1 and 4 seeds representing 12.9% were damaged on row 2. During the third test 5 seeds representing 14.29% were damaged on row 1 while 4 seeds representing 12.5% were damaged on row 2. The theoretical field capacity of the developed planter is 0.22ha/h while the actual field capacity of the developed planter ranges between 0.15 ha/h to 0.17 ha/h with an average of 0.16 ha/h which is close to that obtained by [7, 8]. The average time required to plant a hector of land with the developed planter is 6 hours 15 minutes. The field efficiency of the developed planter ranges between 68.18% and 77.27% with an average of 72.73% which closely agrees with that obtained by [7, 9]. The planter was design to establish 53,333 stands/ha. The actual plant population of the developed planter as presented on Table (1) ranges between 38379 stands/ha to 39157 stands/ha with an average of 38725 stands/ha. The planter needs to be modified to establish close to the required plant population.

4 CONCLUSION

Two rows maize planter with single horizontal plate seed metering mechanism was design and constructed with locally available materials to reduce the drudgery involve in maize planting and to improve the timeliness of the planting operation. The developed maize planter is made to be of low cost and easy to be operated by a single person. The machine was able to establish 38,725 stands/ha at an average field efficiency of 68.18%, the field capacity of the developed planter is 0.16 ha/h with an average seed damage of 13.3% and an average missing rate of 17.5%. The average intra row spacing of the developed planter in 34.4 cm. The overall performance of the developed maize planter was acceptable and the machine can be adopted for use in planting maize. The machine should be operated at a normal walking speed of between 2 -3 km/h to obtained a good result from the machine.

REFERENCES

1. Adewunmi, T. (2004). Performance Evaluation of a Locally Developed Maize Sheller with Husking and Winnowing Capabilities. In: Proceedings of the fifth International Conference of the Nigerian Institution of Agricultural Engineers (NIAE), Ilorin, vol. 26, pp. 68-72.

2. Ikechukwu, I.B., Gbabo, A. and Ugwuoke, I.C. (2014). Design and Fabrication of a Single Row Maize Planter for Garden Use. *Journal of Advancement in Engineering and Technology*, vol. 1, no. 2, pp: 1-7.
3. Larry, S. (2012). The importance of Corn. Available at "<https://www.lathamseeds.com/2012/06/the-importance-of-corn/>" retrieved on 17/03/2020.
4. Karima, O.Y. (2016). Effects of magnetic treatment of water on the growth, yield and quality of maize. *Nigerian Journal of Technological Research*, vol. 11, no. 2, pp 1-7.
5. Knoema (2019). Nigeria - Maize production quantity. Available at <https://knoema.com/atlas/Nigeria/topics/Agriculture/Crops-Production-Quantity-tonnes/Maize-production> retrieved on 28/07/2020.
6. Patterson, O.B. (2016). Four planting devices for planting no-till maize”, *International Journal of Development and Sustainability*, vol. 5, no. 5, pp. 213-219.
7. Alhassan, E.A., Adewumi, A.D. and Okpodjah, B. (2018). 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 (IJMET)*, vol. 9, Issue 10, pp. 349–358, Available online at <http://www.iaeme.com/ijmet/issues.asp?JType=IJMET&VType=9&IType=10>.
8. Gambari, A.B., Bello, K.I. and Soyemi, Y.W (2017). Development and Performance Evaluation of a Manually Operated Two-Row Maize Planter. *International Conference of Science, Engineering & Environmental Technology (ICONSEET)*, vol. 2, no. 11, pp. 78-86.
9. Ani, O.A., Uzoejinwa, B.B. and Anochili, N.F. (2016). Design, Construction and Evaluation of a Vertical Plate Maize Seed Planter for Gardens and Small Holder Farmers. *Nigerian Journal of Technology (NIJOTECH)*, vol. 35, no. 3, pp. 647-655.
10. Olajide, O.G. and Manuwa, S.I. (2014). Design, Fabrication and Testing of a Low-cost Row-Crop Planter for Peasant Farmers. *Proceedings of the International Soil Tillage Research Organisation (ISTRO) Nigeria, Symposium, Akure 2014 November 3 - 6, Akure, Nigeria*, pp. 94-100.
11. Ikechukwu, A., Ibukun, B. and Ikechukwu, C.U. (2014). Design and Fabrication of a Single Row Maize Planter for Garden Use. *Journal of Advancement in Engineering Technology*, vol. 2, no. 1, pp. 1-7.
12. Sanaullah *et al.* (2015). A Textbook of Applied Mathematics-I for Math–113 First year Diploma of Associate Engineer, pp. 357-367. Available at http://www.pbte.edu.pk/text%20books/dae/math_113/Chapter_18.pdf Retrieved on 02/07/2020
13. Khurmi, R.S. and Gupta, J.K. (2012). A Textbook of Machine Design (1st multicolour edition) Eurasia Publishing House (PVT.) LTD New Delhi, pp. 516-530.
14. Rabbani, M.A., Hossain, M.M., Asha, J.F. and Khan, N.A. (2016). Design and development of a low cost planter for maize establishment. *Journal of Science, Technology and Environment Informatics*, vol. 4, no. 1, pp. 270-279.
15. Kalay, K. and Moses, S.C. (2017). Performance Evaluation of Manually Operated Multi-Crop Planter for Okra. *Journal of Pharmacognosy and Phytochemistry SP1*, pp. 264-269.
16. Oduma, O., Edeh, J.C. and Onu, O.O. (2014). Performance Evaluation of a Locally Developed Three-Row Maize Planter. *International Journal of Agricultural Science and Bioresource Engineering Research*, vol. 3, no. 4, pp. 1-11. Available online at <http://www.ijasber.com>.