

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: www.ijirset.com

Vol. 8, Issue 6, June 2019

Design and Fabrication of a Pulse Planter for Conservation Agriculture

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ABSTRACT: Conservation agriculture is based on optimizing yields and profits, to achieve a balance of agricultural economic and environmental benefits, thus, there is need to make available various equipment to be used in this system of agriculture. A pulse planter that is cheap, affordable by rural farmers, easy to maintain and less laborious to use was developed for use in conservation agriculture. The planter has the capability of delivering the seeds precisely with uniform depth in the furrow at uniform spacing between the seeds. The planter consists of the main frame, adjustable handle, seed hopper, seed metering device, adjustable furrow opener, furrow coverer, drive wheels, seed tube and disc couler. All the parts were fabricated from mild steel except for the seed tube which was made from rubber material. The pulse planter is incorporated with a couler to cut residue and thrashes on the soil after clearing. The drive shaft of the planter controls the seed plate shaft through the aid of a bevel gear.

KEYWORDS: Conservation agriculture, Pulse planter, couler disc

I. INTRODUCTION

Most crops grown in Asia, Africa and Latin America are based on subsistence agriculture mainly from resource-poor small holder farmers. This form of agriculture is characterized by limited application of inputs, distorted markets, deteriorating soil conditions, and now increasingly uncertain weather patterns [1]. The factors leading to soil degradation over time include limited organic matter returns to the soils, minimal and unbalanced fertilizer addition, limited options for crop rotation and the perceived need for regular tillage. Small holder farmers generally try to maximize tillage, within their constraints of time, labour and available implements, primarily for the purpose of weed management and to create a seed bed with a fine soil tilth suitable for germination and seedling establishment [7].

Small holder farmers who primarily relies on rainfall rather than irrigated systems have generally not adopted conservation agriculture practices owing to lack of knowledge about conservation agriculture and how it could potentially improve their own agriculture, the perceived complexity of this new cropping system, unavailability of appropriate minimum tillage implements, limited access to herbicides, and the change of mind set required to shift from the habits of multiple tillage to minimum tillage [12]. However, opportunities are opening up to make it easier for small holder farmers to change from excessive tillage to various forms of minimum tillage. There are options using hand or animal-drawn implements [11] and increasingly for planters mounted on two-wheel tractors. There have been innovations made to both two-wheel tractor as well as animal-drawn direct seeding implements that do permit adequate seeding into minimally disturbed soil [4]. This provides the opportunity to introduce conservation agriculture among small holder farmers, not only in terms of reduced soil disturbance but also with respect to biomass cover and crop rotation. Effective conservation agriculture practices for small holders would also enable them to capture the economic benefits already enjoyed by the large-scale users of conservation agriculture, reduce fuel and labour costs and improve timeliness of operations [5].

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II. PULSES

Pulse crops belong to the legume family of plants. Their seed is used for human food and livestock feed. They occupy more than 160 million acres of the world's crop land and are exceeded only by wheat, corn, rice, and barley in harvested acreage[10]. The eleven major groups of pulse crops in world acreage are dry bean, dry broad bean, field peas, chickpea, cowpea, faba bean, pigeon pea, vetch, lentil, and lupine[2]. Soybeans and peanuts are often used as pulse crops, but their major uses are for oil and the protein meal remaining after oil extraction, so they are classified as oilseed crops[9].

Pulse crops have a unique combination of advantages for human food and livestock feed. The seeds contain more protein than needed for human nutrition in contrast to grain crops, which lack sufficient protein. Furthermore, pulse protein is relatively high in the lysine and tryptophan amino acids that are usually low in grain crops. Consequently, pulses in the diet supplement the low percentages of protein present in foods made from grain crops. Pulse seeds will keep for many years in dry storage and can be processed for food in the home. Consequently, pulses are compatible with the subsistence type of agriculture needed in developing countries. Farmers using pulse crops as carbohydrate and protein concentrate feeds can reduce or eliminate cash purchases of urea, anhydrous ammonia, and protein meals commonly used as protein concentrates [10].

III. MATERIALS AND METHODS

The pulse planter in Figure 1 was developed at the Department of Agricultural and Environmental Engineering, Federal University of Technology, Akure, Nigeria. The features of the planter include adjustable handle, seed hopper, seed metering device, adjustable furrow opener, furrow coverer, drive wheels, seed tube and disc coulters.

- (i) **Seed hopper:** The hopper is cylindrical in shape which is open at one end and closed at the other end with an opening to allow seed into the seed tube. The height is 300 mm while the width is 200 mm. The material used for the design is 3 mm thick mild steel sheet metal. To ensure free flow of seeds, a bowl which is hemispherical in shape with 160 mm diameter is placed in the hopper to create a slope of about 30° , which is higher than the average angle of repose of the seeds [8].
- (ii) **Seed metering mechanism:** The seed metering mechanism used for this work is made of 200 mm diameter and 5 mm thickness mild steel. On the disc are two cylindrical cells bored equidistant from each other along the periphery. The dimensions are such that two seeds can be accommodated if they are oriented on the major axis. The dimensions of cells are 197 mm in diameter and 5 mm deep. Seeds from the hopper pass through the cells to the discharge sprout at intra row spacing of 30 cm. The plate is welded on a vertical shaft driven by gear in mesh with another gear driven by the ground wheel.
- (iii) **Seed tube:** Seeds metered out by the cells travel through the tube before they are deposited in the furrow. The seed tube is located below the seed plate attached to the cell opening. The material used for the design is a cylindrical pipe of 15 mm diameter on which a rubber tube is attached. A rubber material was used in order to prevent the seeds from damage.
- (iv) **Transport Wheels:** The transport wheels are made of mild steel which is an integral part of the seed metering mechanism. The wheels have shaft which bear a gear mechanism that rotates the metering mechanism. The surfaces of the transport wheels are fixed with 10 mm long steel cut from 10 mm diameter iron rod that provide necessary soil rolling resistance during forward movement of the planter. The circumference of the wheel is designed such that it is twice the required seed spacing within the row to enable the planter discharge twice in every one revolution of the wheels.
- (v) **Furrow Opening Device:** The furrow opening device is made of mild steel angle iron of 2 mm thickness with a length of 360 mm. The mild steel is slightly beveled at the lower edge (5°) to facilitate an easy cut through the soil. Bolts and nuts were used to fasten the device to the frame through a hole drilled on the frame. The hole is adjustable to vary the depth at which the furrow opener will operate.
- (vi) **Furrow Covering Device:** The furrow covering device is made of rectangular mild steel plate of dimension 80 mm by 120 mm. It was fastened with bolt and nut to the frame through a hole drilled on the frame. The

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furrow covering device is perpendicular to the direction of travel of the planter to facilitate proper covering of the soil.

- (vii) **Handle:** The handle consists of two hollow pipes of 30 mm internal diameter, each having a length of 815 mm. The handle is adjustable to take care of differences in height of operators.

The design of a conservation agriculture planter for planting pulses is based on the following considerations:

- The planter is simple in design with the use of locally available materials for the fabrication of the component parts.
- The ease of fabrication of the component parts with simple joinery methods.
- The planter is light in weight for easy transportation.
- Affordability of the planter to small-holder farmers.
- The planter is easy to operate.
- Effectiveness in planting as a conservation planter.

The following design calculations were carried out for the machine analysis;

i. Determination of weight of hopper material

The material used for constructing the hopper is made of mild steel having a density of 7840 kg/m^3 .

Figure 1 shows the shape of the hopper.

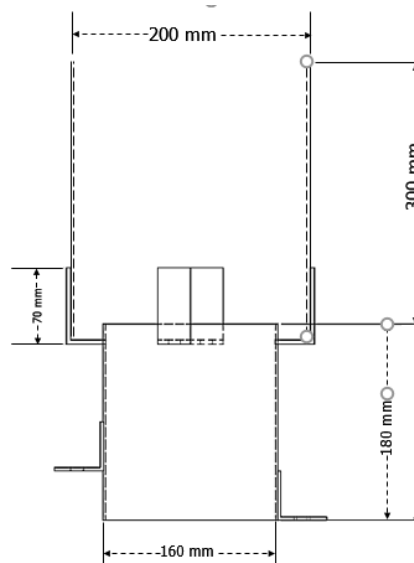


Fig 1: Diagram showing the shape of the hopper

The weight of the hopper material is calculated using the equation:

$$A_{HM} = (\pi R^2 + 2\pi RH) + 2\pi rh \quad (1)$$

$$V_{HM} = A_{HM} \times t_{HM} \quad (2)$$

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

$$W_{HM} = M_{HM} \times \text{Acceleration due to gravity} \quad (4)$$

where,

A_{HM} = Surface area of the hopper material (m^2)

V_{HM} = Volume of the hopper material (m^3)

t_{HM} = Thickness of the hopper material (m)

M_{HM} = Mass of the hopper material (kg)

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ρ_{HM} = Density of the hopper material(kgm^{-3})

W_{HM} = Weight of the hopper material(N)

R = Radius of the hopper (m)

r = radius of the bevel gear housing (m)

H = height of the hopper (m)

h = height of the bevel gear housing (m)

The weight of the hopper material for the two hoppers is determined as 191 N.

ii. Determination of weight of main frame material

The weight of the main frame material is determined using the equations:

$$A_{MFM} = \left[2\left[\frac{1}{2}(a+b)h\right] + (LB+lb) \right] + \left[2\left[\frac{1}{2}(a+b)h\right] + (LB+lb) \right] + [W_{MFM} + (W_{MFM} - t_{MFM})](2L + 2l) \quad (5)$$

$$V_{MFM} = A_{MFM} \times t_{MFM} \quad (6)$$

$$M_{MFM} = V_{MFM} \times \rho_{MFM} \quad (7)$$

$$W_{MFM} = M_{MFM} \times \text{Acceleration due to gravity} \quad (8)$$

where,

a = length of upper side of angle bar (m)

b = length of lower side of angle bar (m)

h = height of the angle bar (m)

l = length of the shorter bar (m)

L = Length of the longer bar (m)

A_{MFM} = Surface area of the main frame material (m^2)

w_{MFM} = Width of the main frame material(m)

V_{MFM} = Volume of the main frame material(m^3)

t_{MFM} = Thickness of the main frame material(m)

M_{MFM} = Mass of the main frame material(kg)

ρ_{MFM} = Density of the main frame material(kgm^{-3})

W_{MFM} = Weight of the main frame material(N)

The weight of the main frame material is determined as 219.9 N.

iii. Determination of the weight of grain

The weight of grain is dependent on the maximum capacity of the hopper. The volume of the hopper is then determined using the following equation:

$$V_H = \pi R^2 H - \frac{2}{3} \pi r^3 \quad (9)$$

where,

V_H = Volume of hopper (m^3)

R = Radius of the hopper (m)

H = Height of the hopper(m)

r = radius of the hemispherical bowl (m)

From equation 9, the weight of grain is then determined as:

$$M_G = V_H \times \rho_G \quad (10)$$

(10)

$$W_G = M_G \times \text{Acceleration due to gravity} \quad (11)$$

(11)

where,

M_G = Mass of grain(kg)

ρ_G = Density of grain is 750 kg/m^3 (Jayan and Kumar, 2004)

W_G = Weight of grain(N)

The weight of grain for the two hoppers is 132 N.

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iv. Determination of the Weight of grain resting on shaft

The weight of grain resting on shaft is determined using the following equations:

$$V_{GRS} = (\pi R^2 - \pi r^2) \times h \quad (12)$$

$$M_{GRS} = V_{GRS} \times \rho_G \quad (13)$$

$$W_{GRS} = M_{GRS} \times \text{Acceleration due to gravity} \quad (14)$$

where,

V_{GRS} = volume of grain resting on shaft(m^3)

M_{GRS} = mass of grain resting on shaft(kg)

W_{GRS} = weight of grain resting on shaft(N)

r = radius of hemispherical bowl (m)

R = Radius of hopper material (m)

h = height of hopper material (m)

The weight of grain resting on shaft is determined as 88.8N

v. Determination of the weight of grains resting on the hopper

The weight of grain resting on the hopper is obtained as:

$$W_{GRH} = W_G - W_{GRS} \quad (15)$$

where,

W_{GRH} = Weight of grain resting on hopper

W_G = Weight of grain

The weight of grain resting on the hopper is determined as 43.2 N

vi. Determination of the maximum bending moment

Figure 2 shows the load distribution on the shaft.

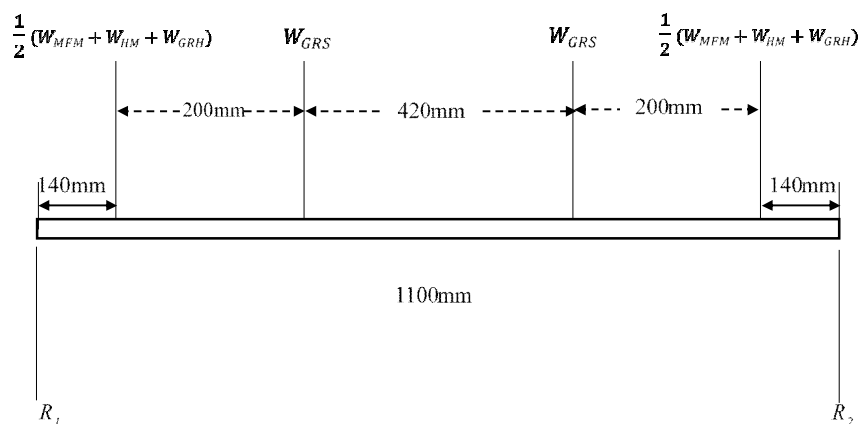


Fig. 2: Load distribution on the shaft

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The following expressions may be used to calculate the reactions at the support.

$$R_1 + R_2 = 2 \times \frac{1}{2} (W_{MFM} + W_{HM} + W_{GRH}) + 2 \times W_{GRS}$$

$$R_1 = \frac{1}{1.1} \left[\frac{1}{2} (W_{MFM} + W_{HM} + W_{GRH}) \times 0.96 + W_{GRS} \times 0.76 + W_{GRS} \times 0.34 + \frac{1}{2} (W_{MFM} + W_{HM} + W_{GRH}) \times 0.14 \right] \quad (16)$$

where,

R_1, R_2 = Reactions at the support(N)

W_{GRH} = Weight of grain resting on the hopper(N)

W_{GRS} = Weight of grain resting on the shaft(N)

Using the method of sectioning, the following expressions were obtained for the bending moment.

$$M_{b1} = R_1 \times 0.14$$

$$M_{b2} = R_1 \times 0.34 - \frac{1}{2} (W_{MFM} + W_{HM} + W_{GRH}) \times 0.2$$

$$M_{b3} = R_1 \times 0.76 - \frac{1}{2} (W_{MFM} + W_{HM} + W_{GRH}) \times 0.62 - W_{GRS} \times 0.42$$

$$M_{b4} = R_1 \times 0.96 - \frac{1}{2} (W_{MFM} + W_{HM} + W_{GRH}) \times 0.82 - W_{GRS} \times 0.62 - W_{GRS} \times 0.2$$

The maximum value of 62Nm is chosen as the bending moment of the shaft.

vii. Determination of the Shaft Diameter

Design of shafts of ductile material based on strength is controlled by maximum shear theory. The material for the shaft is mild steel rod. For a shaft having little or no axial loading, the diameter may be obtained using the ASME code equation (Khurmi and Gupta, 2005) given as:

$$d^3 = \frac{16}{\pi S_a} \sqrt{(k_b M_b)^2 + (k_t M_t)^2} \quad (17)$$

where,

d = Diameter of the shaft(m)

M_b = Bending Moment (Nm)

M_t = Torsional Moment (Nm)

k_b = Combined shock and fatigue factor applied to bending moment

k_t = Combined shock and fatigue factor applied to torsional moment

S_a = Allowable stress = 40 MNm⁻² (for shaft with key way)

For rotating shafts, when load is suddenly applied (minor shock) (Khurmi and Gupta, 2005):

$$k_b = 1.5 \text{ to } 2.0 \quad k_t = 1.0 \text{ to } 1.5$$

For shaft without key way, allowable stress, $S_a = 55 \text{ MN/m}^2$

For shaft with key way, allowable stress, $S_a = 40 \text{ MN/m}^2$

A shaft diameter of 25 mm was obtained.

viii. Determination of the Capacity of the Planter

The capacity of the planter may be determined in terms of the area of land covered per time during planting or the number of seeds planted per time of planting. The capacity of the planter in terms of the area of land covered per time may be obtained from the following expression.

$$C_{PA} = \frac{\text{Area covered by planter}}{10000 \text{ m}^2} \quad (18)$$

C_{PA} = Capacity of planter (hectare/h)

Area covered by planter = (Inter – row spacing) × (Distance covered by planter) (m²/minute)

Distance covered by planter = (Speed of planter) (m/minute) × (Time of planting) (m)

The distance covered by the planter is obtained as 77.9 m while the area covered by the planter is obtained as 3895 m²

Thus, the capacity of the planter is obtained as 0.3895 ha/h

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IV. FABRICATION OF THE MACHINE

All the parts of the conservation agriculture planter for planting pulses were fabricated in the workshop of the Department of Agricultural and Environmental Engineering, Federal University of Technology, Akure. All the parts of the planter were fabricated with mild steel material except for the seed tube which was made from rubber material. The choice of rubber material for the seed tube was because the coefficient of restitution for rubber material is lower than that of mild steel sheet of the same thickness. The rubber material will go a long way in minimizing seed bouncing, thereby protecting the seeds from damage due to impact.

The hopper was fabricated using 3 mm thick mild steel metal sheet. The main frame which supports other component parts of the planter was fabricated using mild steel flat bar having a length of 110 cm and width of 80 cm. The adjustable handle for the planter was fabricated using a combination of 25.4 mm mild steel circular pipe and 25.4 mm mild steel angle bar. The adjustable furrow opener and furrow coverer were both fabricated using a 60 mm by 5 mm mild steel flat bar. The planter's ground wheel were fabricated using a combination of both 25.4 mm mild steel square pipes and 3 mm thick mild steel flat bars. Figures 3 shows the orthographic drawing of the pulse planter with necessary dimensions.

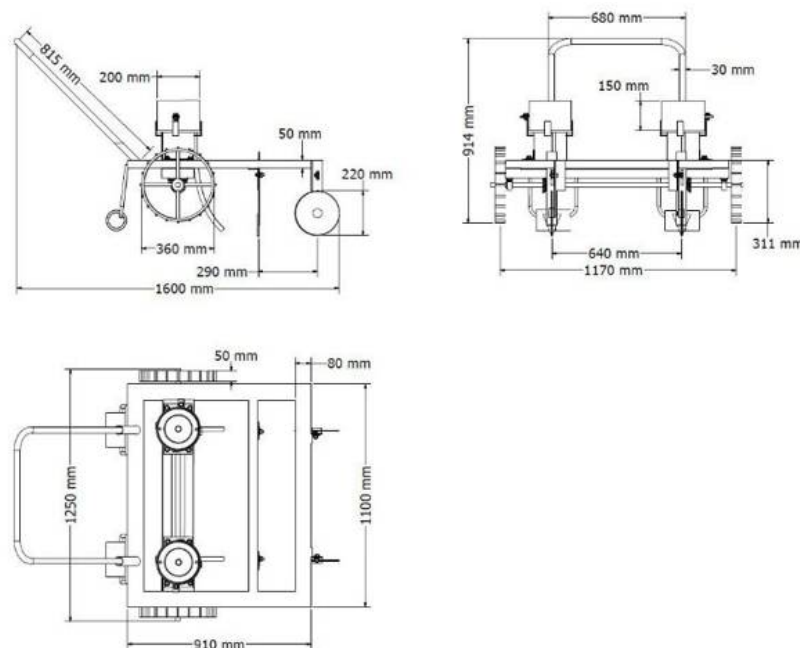


Fig. 3: Orthographic drawing of the pulse planter

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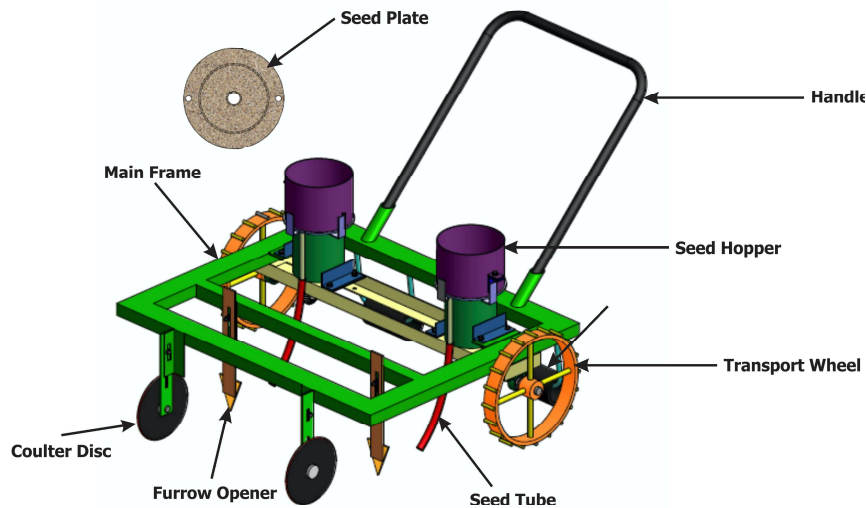


Fig. 4: 3D diagram of the pulse planter

Figure 4 shows the three-dimensional drawing of the pulse planter with the parts description.

PART LIST		
S/N	Description	Qty
1	Hopper	2
2	Soil Coverer	2
3	Handle	1
4	Main Frame	1
5	Coulter	2
6	Furrow Opener	2
7	Land Wheel	2
8	Bearing	2
9	Seed Plate	2
10	Bevel Gear	2
11	Shaft	1
12	Seed Tube	2

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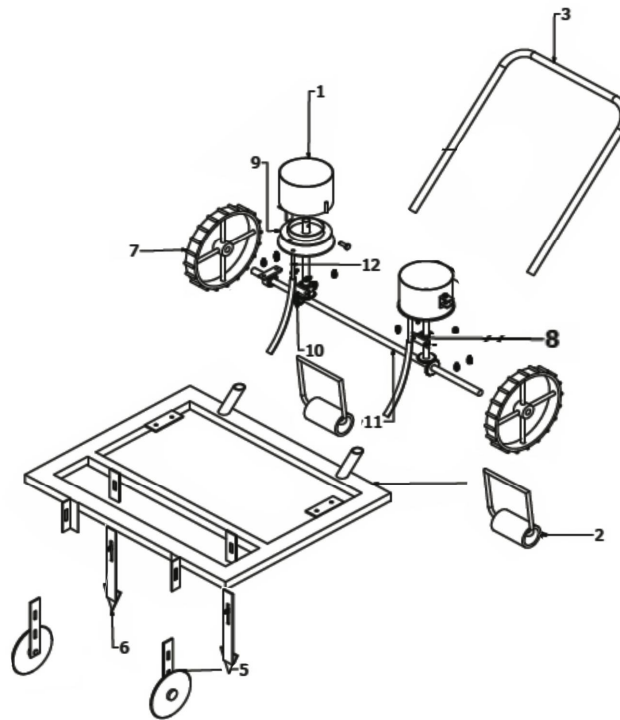


Fig. 5: Exploded view of the pulse planter

Figure 5 above shows the exploded view of the pulse planter showing the order of assembly of various parts.



Fig. 6. Photograph of the fabricated conservation planter

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Figure 6 shows the photograph of the fabricated planter. The drive shaft of the designed planter directly controls the seed plate through the aid of a bevel gear mechanism which eliminates completely the attachments with chain drive system which will increase the planter's cost of production, thereby increasing efficiency at a highly reduced cost.

V. CONCLUSIONS

Due to the benefit of practicing conservation agriculture, the small-holder farmer needs to be provided with the equipment needed for this type of cultivation system. This work focused on the design and fabrication of a pulse planter that can be used for this type of cultivation system. The planter is cheap, easily affordable, easy to maintain and less laborious to use. The planter will go a long way to make farming more attractive as it tends to increase agricultural output. All the parts of the planter were fabricated from mild steel material except for the seed tube which was made from rubber material. The drive shaft of the planter controls the seed metering mechanism through the help of a bevel gear which transmits the motion of the drive shaft at right angle to the shaft of the seed plate. This eliminates complexities in the power transmission system of the planter which increases the planter's cost of production.

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