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Performance Evaluation of a Pulse Planter Developed For Conservation Agriculture

T. Osadare[1]and S.I. Manuwa[2]
[1]Department of Agricultural and Bio-Environmental Engineering*
The Federal Polytechnic, Ado-Ekiti, Ekiti State, Nigeria.
[2]Department of Agricultural and Environmental Engineering,
Federal University of Technology, Akure, Nigeria.
Corresponding Author: T. Osadare

Abstract*: 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 was designed and evaluated for no-till conditions. It has the capability of delivering the seeds precisely with uniform depth in the furrow at uniform spacing between the seeds. The planter is incorporated with a coulter 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.The results obtained from the trial tests showed that the planter functioned properly with a seed rate of 0.96 kg/h, the average seed spacing for field test is 28.6 cm and the average percentage of seed damage is 6.84. The field efficiency of 76.8% and average field capacity of 0.67 ha/h were obtained from the test. The estimated cost of the planter is ₦74,602.*

Keywords: *Pulses;Conservation agriculture; Pulse planter; Field efficiency; Field capacity*

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I. Introduction

Conservation tillage systems maintains crop residue on or near the surface to control soil erosion (Allmaras and Dowdy, 1985). Such system requires that at least 30% of the surface of soil be covered with crop residue (Morrison and Allen, 1987; Jasa et al., 1991).

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 (Wall, 2007). 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 (Thierfelder and Wall, 2010) 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 (Hobbs, 2007). 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 (Hobbs, *et al.*, 2008).

1.1 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 (Robinson, 1975). The eleven major groups ofpulse crops in world acreage are dry bean, dry broad bean, field peas, chickpea, cowpea, faba bean, pigeon pea, vetch, lentil, and lupine(FAO, 2004). 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 (Pulse Canada, 2017).

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 (Robinson, 1975)

II. Materials And Methods

2.1 Description of the Planter

The developed pulse planter consists of the adjustable handle, seed hopper, seed metering device, adjustable furrow opener, furrow coverer, drive wheels, seed tube and disc coulter.

(i) **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.

(ii) **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 30^0, which is higher than the average angle of repose of the seeds (Mohammad *et al.*, 2010).

(iii) **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.

(iv) **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.

(v) **Seed discharge 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.

(vi) **Furrow Opening Device:** The furrow openingdeviceis 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 (5^0) 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.

(vii) **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 furrow covering device is perpendicular to the direction of travel of the planter to facilitate proper covering of the soil.

2.2 Design Considerations

The factors considered in the design of the conservation agriculture planter for planting pulses are as follows:

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

2.3 Planter Operation

The hopper was filled with pulse seed (cowpea) grown by local farmers in Akure, Ondo State, Nigeria. The filling of the hopper depends on how much area of the field to be covered. As the planter was pushed forward in the direction of travel at an average speed of 0.15 m/s, the pointed bar type furrow opener penetrated the soil creating a furrow for seeds to be placed. The planter's ground wheel is connected directly to the seed metering device through a bevel gear and as the wheel rotates, the seed metering device placed at the bottom of the hopper also rotates, thereby releasing two or three seeds depending upon the size of the seeds. These seeds are then conveyed to the furrow through the seed tube. The furrow was then closed by the furrow coverer.

2.4 Performance Test

Trial tests were conducted to see if the seed metering mechanism, furrow opener and covering device were functioning properly. For a furrow opener, the ability to place the seed at a given sowing depth in the soil is an important factor in evaluating its performance.

2.5 Laboratory Test

The machine was calibrated in the laboratory to determine the rate of seed discharge, uniformity of seed spacing and seed damage during operation.

2.5.1 *Calibration Test*

The hopper of the planter was loaded with 4 kg of cowpea seeds. The planter was jacked up to allow for free rotation of the transport wheels. A mark was made on the wheels to indicate the reference points to count the number of revolutions when turned, and a bowl was placed on each of the seed discharge tube to collect the seeds discharged. The transport wheels were rotated 100 times at low speed as would be obtained on the field. A stop watch was used to measure the time taken to complete the revolutions. The seeds collected in the bowl was weighed on a balance and the procedure was repeated ten times.

2.5.2 *Uniformity of Seed Spacing*

To determine the uniformity of seed spacing, 4 kg of seeds were loaded into the hopper and 10 m was marked out on the plain ground and the machine was run within the length at walking speed and the time of travel was recorded. A measuring tape was used to measure the distance between successive drop of seeds. This process was repeated five consecutive times and measurement of distance between successive drop of seeds were recorded.

2.5.3 *Test for Seed Damage*

The planter was jacked up as in calibration test and 4 kg of seeds were loaded in the hopper. The wheels were rotated 30 times in turns and the time taken to complete the revolution was recorded with the aid of stop watch. The seeds discarded from the seed tube were inspected for damage and recorded.

2.6 Field Test

A field of 10 m × 10 m was used for the performance test of the planter. The plot which has been used for the cultivation of maize was cleared and left for about five days so that the thrashes (which consist of the dried maize stalks and average grown weeds of about 20 – 30 cm height) have turned into surface mulch before the planter was tested. The field efficiency, field capacity, planting depth of seeds and uniformity of seed spacing were determined.

2.6.1 *Field Efficiency*

To determine the field efficiency, the planting operation was performed by running the planter at constant forward speed as determined by observing the distance of travel using measuring tape and the corresponding time to complete the distance with the aid of a stop watch while planting the area of the prepared field. The effective operating time and the time spent to fill the seed hopper, remove clogged up thrashes and other obstructions were recorded. The field efficiency was calculated from equation (24) proposed by Kepner et. al., (1978).

$$\varepsilon = \frac{100T_e}{T_t} \tag{1}$$

where ε = field efficiency (%)

T_e = effective operating time (min)

T_t = total time (min)

2.6.2 *Effective Field Capacity*

The effective field capacity was determined by measuring the effective width of the machine using a measuring tape and the forward speed of planting operation, the effective field capacity was then evaluated from equation (2) proposed by Kepner *et al*., (1978).

$$C_e = \frac{ws}{1000}\varepsilon \tag{2}$$

where C_e = effective field capacity (ha/hr)

w = implement effective width, m

s = forward speed, km/hr
ε = field efficiency (%)

2.6.3 *Planting Depth*

The average depth of the seed placement was determined by running the planter to and fro over an area of 10 square metres without the furrow covering device and with medium setting of the furrow opener (Bamgboye and Mofolasayo, 2006). During the process, the time taken to travel the length of the field was recorded to determine the average speed of operation in the field. Along each furrow, five hills were randomly sampled and investigated for depth of planting. A measuring tape was used to measure the required depth.

2.6.4 *Uniformity of Seed Spacing*

After seed germination, two (2) weeks after planting, the distances between successive seedlings within the row were determined for the whole area of land planted using a measuring tape. All operational and adjustment problems were detected and rectified during the field operation of the planter.

III. Results And Discussion

The fabricated pulse planter is presented in Figure 1 and 2.

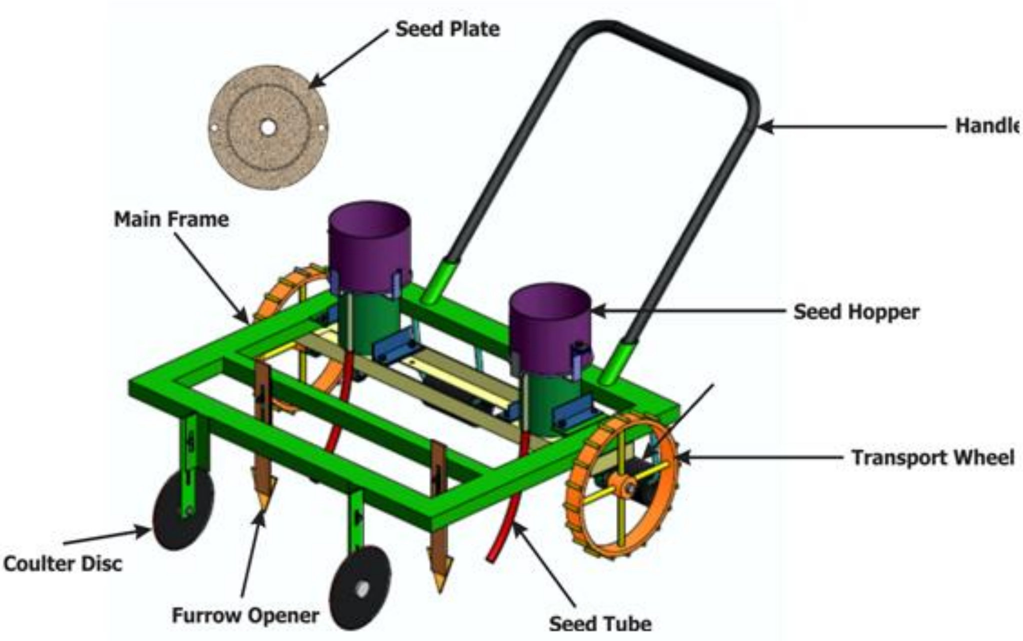

Fig. 1: 3D diagram of the pulse planter

Fig. 2: Photograph of the fabricated pulse planter

3.2.1 *Calibration*

Table 1 show the results obtained from the calibration of the pulse planter. It was observed from the table that the average weight of seeds discharged from the hopper is 19.8 g. The planter was able to meter out average of three seeds per discharge and has an average seed rate of 0.96 kg/h.

Table 1: Planter calibration

Replications	Weight of seeds discharged (g)	Time for 25 rev (min)	Speed (rpm)
1	18.0	1.21	30.0
2	21.0	1.06	28.2
3	22.0	1.07	27.0
4	19.0	1.45	29.4
5	18.0	1.33	30.0
6	20.0	1.04	30.4
7	21.0	1.23	28.8
8	19.0	1.46	30.6
9	18.0	1.38	32.4
10	22.0	1.09	29.8
Total rate	**198.0**	**12.32**	
Mean	19.8	1.23	
Seed rate =	**0.96kg/h**		

It was observed that at lower speed of 27.0 rev/min, the weight of seed discharged was higher than at higher speed of 32.4 rev/min. This agreed with that reported by Bamgboye and Mofolasayo (2006). The planter design performance was satisfactory because the expected number of seeds were discharged from the metering device and the planter function best at low speed.

3.2.2 *Uniformity of Seed Spacing*

Table 2 presents the intra-row plant spacing measured in the laboratory and on the field determined after germination (2 weeks after planting). In the test conducted in the laboratory, the average intra-row seed spacing was 29.6 cm while in the field, the spacing obtained was lower with value of 28.6 cm.

Table 2: Laboratory and field determination of uniformity of seed spacing in row

Replications	Time (s)	Speed (m/s)	Laboratory spacing (cm)	Field Spacing (cm)
1	30	0.6	31	25
2	30	0.6	28	37
3	30	0.6	30	35
4	30	0.6	29	20
5	30	0.6	30	26
Mean	30	0.6	29.6	28.6

The result of laboratory and field test shows uniformity in the plant spacing and gave close intra-row spacing to 30 cm as recommended by the Savanna Agricultural Research Institute (SARI). However, the slight discrepancies in the results may be due to seed clogging and other operational factors.

3.2.3 *Seed Damage*

Table 3 shows the total average percentage of seed damage incurred during operation. It is observable from the table that the percentage average damage is 6.84%.

Table 3: Percentage seed damage during operation

Replications	Time for 25 (rev/sec)	Speed (rpm)	No of seeds discharged	No of damaged seeds	Percentage damage (%)
1	48	30.1	136	12	8.8
2	47	28.8	125	8	6.4
3	50	27.6	142	6	4.2
4	52	28.6	130	10	7.7
5	48	29.3	128	8	6.3
6	49	30.4	140	10	7.1
7	50	29.5	133	8	6
8	47	33.2	128	11	8.6
9	49	29.5	122	8	6.6
10	51	28.5	135	9	6.7
Mean	**49.1**	**29.55**	**131.9**	**9**	**6.84**

The damage is high compared to 4.51% obtained for Two-Row Okra planter (Bamgboye and Mofolasayo, 2006). The damage may be due to the speed of rotation of the transport wheels and the rubbing action between the metering device and the seed hopper which is metal to metal contact. Damage can be reduced if the metering device is made of non-metallic material such as Teflon and the machine is operated at a uniformly low speed.

3.2.4 Field Efficiency and Effective Field Capacity of the planter

Table 4 reveals the field efficiency of the planter obtained from the field test. From the result, the field efficiency of the machine is 76.8% and the result of the field capacity according to the table showed average value of 0.67 ha/hr.

Table 4: Field efficiency and effective field capacity of the planter

Activity	Time for 1/10 hectare(s)	Time/hectare (min)
Turning at field end	40	6.7
Stumping/cods removal	120	20
Setting/adjustment	60	10
Actual planting	730	121.7
Total time	950	158.3
Field efficiency (%)	**76.8**	
Effective field capacity (ha/h)	**0.67 ha/h**	

This shows a good and satisfactory performance as it was within the range of values obtained for planting operation by investigators (Kepner *et al*., 1978; Bamgboye and Mofolasayo, 2006). The value is higher than that of the manually operated seeding attachment of 0.28 ha/h for an animal drawn cultivator developed by Kumar *et al*., (1986) and that of template row planter developed by Adisa and Braide (2012) and that of row crop planter (0.36 ha/h) developed by Olajide and Manuwa (2014) which was of a single row type. This satisfactory result is due its maneuverability which saves time in moving and turning the planter from one point to another.

3.2.5 Planting Depth

Table 5 presents the planting depth measurement recorded in the determination of the average depth of the furrow opened for the planting of the seeds. The average planting depth of furrow opened is 2.25 cm.

Table 5: Average planting depths of the seeds

Replications	Planting depth (cm)
1	2.02
2	2.04
3	1.92
4	2.68
5	1.88
6	1.72
7	2.72
8	2.75
9	2.81
10	1.95
Mean	**2.25**

This value is greater than the mean depth of furrows in the manually operated cowpea precision planter developed by Oduma*et al*., (2014) which was 2.22 cm. The value is within the range of 2-4 cm proposed by Shepherd and Bhardwaj, (1986) for peas. The operation of this planter on the field was without much difficulty due to the condition of the soil. The furrow opening device can always be adjusted to suit the planting depth needed as the topography of the land demanded.

IV. Conclusions

A pulse planter, affordable by rural farmers, easy to maintain and use had been developed for use in conservation agriculture. Most of the parts of the planter were fabricated from mild steel material, the seed tube which was made from rubber material while the shaft, bevel gear and bearing were bought out. The results obtained from the trial tests showed that the planter functioned properly with a seed rate of 0.96 kg/h, the average seed spacing for field test is 28.6 cm and the average percentage of seed damage is 6.84%. The field efficiency of 76.8% and average field capacity of 0.67 ha/h were obtained from the test.

With proper attention to its maintenance which may include regular lubrication of moving parts, replacement of worn-out/damaged parts, cleaning and proper storage after use, this equipment will be very useful in practicing conservation agriculture and adequately alleviate the farmers' difficulties in pulse production.

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