DEVELOPMENT AND PERFORMANCE EVALUATION OF A FOUR ROW ANIMAL DRAWN MAIZE SEED PRECISION PLANTER

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A DISSERTATION SUBMITTED TO THE SCHOOL OF POSTGRADUATE STUDIES, AHMADU BELLO UNIVERSITY, IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF MASTER OF SCIENCE DEGREE IN AGRICULTURAL ENGINEERING

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DECLARATION

I declare that the work in this dissertation entitled "Development and Performance Evaluation of a Four Row Animal Drawn Precision Seed Planter" has been performed by me in the Department of Agricultural and Bio-Resources Engineering. The information obtained from the literature has been duly acknowledged in the text and a list of references provided. No part of this dissertation was previously presented for another diploma or degree at this or any other institution.

AHMED KABIRU		
Name of Student	Signature	Date

CERTIFICATION

This dissertation entitled "DEVELOPMENT AND PERFORMANCE EVALUATION OF A FOUR ROW ANIMAL DRAWN PRECISION SEED PLANTER" by Kabiru AHMED met the regulations governing the award of the degree of Master of science in Agricultural Engineering of Ahmadu Bello University, and is approved for its contribution to knowledge and literary presentation.

Prof. U.S Mohammed
Chairman Supervisory Committee — Signature — Date

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Member, Supervisory Committee — Signature — Date

Prof. M. Isiaka
Head of Department — Signature — Date

Prof. Sani Abdullahi
Dean, School of Postgraduate Studies — Signature — Date

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ABSTRACT

Crop planting is very essential to increase production by facilitating optimum plant population per area and reduce unnecessary competition among crops. It is accomplished by any of broadcasting, seed drilling, single grain sowing, band planting, cross sowing, furrow sowing or hill sowing. This can be achieved by the use of machineries such as planters and seeders. The low field capacity, inaccurate placement of seed at a required depth and intra - row distance, seed damage due to metering, and high cost of imported planters associated with these planters envisage the need for a locally developed and cost effective multi-row animal drawn maize seed precision planter. This study focused on the design, fabrication and evaluating a four row animal drawn maize precision seed planter. The fabrication was done in the Department of Agricultural and Bio-Resources Engineering Workshop, Ahmadu Bello University Zaria. The major components of the planter include the four hoppers, four seed metering units, four delivery tubes, four furrow openers with soil covering devices, four soil pressers, four ground wheel (drive mechanism), two guard wheels for marking out during operation and a single connecting bar (frame) on which the four units are attached and aligned. The machine was evaluated in the experimental field of the department during the 2019 rainy season. Three levels of planting speed (0.6, 0.8 and 1m/s) 'S', three levels of hopper seed quantity (25, 50 and 100%) 'W' and two levels of planting depth (1.5 and 2.5cm) 'D' were assessed. The field experiment was designed in a 3×3×2 randomized complete block design (RCBD). The results obtained showed the effects of planting speed, seed quantity and planting depth were significant on the planting performance of the machine. The result also showed that planting with 50 % seed hopper filled at a planting speed of 0.8 m/s and 2.5 cm planting depth recorded highest mean field efficiency of about 87 % which is significantly different from the other results obtained. Highest mean effective field capacity of 0.59 ha/hr for 25 % seed quantity at 1 m/s planting speed with 1.5 and 2.5 cm planting depth, seed rate of 22.3 kg/ha and highest germination count of 100 % with 100 % seed quantity at 0.6 m/s planting speed and 1.5 cm planting depth were recorded. The average draft required to pull the planter was also 0.96kN. Least mean field efficiency of 56 % for 100 % seed quantity at 1 m/s speed and 1.5 cm planting depth. The mean field capacity of 0.28 ha/hr for 100 % seed quantity at 0.6 m/s planting speed with 1.5 cm planting depth. The seed rate of 17 kg/ha for 100 % seed quantity at 1 m/s speed and least germination count of 73 percent with 50 and 100 % seed quantity at 1 m/s planting speed and 1.5 cm planting depth were recorded. A moderate planting speed and high planting depth gives a better field efficiency when the hopper is half full. With high planting speed and low seed hopper quantity, a best effective field capacity could be obtained while planting depth have no effective on the field capacity. Seed rate and high germination count could be obtained with a decreasing planting speed, depth and high seed hopper quantity. The targeted seed spacing could be achieved with moderate planting speed, but increasing planting depth and seed hopper quantity. Finally, the planting speed, planting depth and seed hopper quantity have no significant effect on seed per hill as the average seed drop across all the treatment is one seed.

In conclusion, planting at 0.6 and 0.8 m/s, with 50 and 100 % seed hopper capacity and 2.5 cm planting depth result in maximum planting performance. With these combinations, optimum seed spacing, seed depth, germination count, seed rate together with high field efficiency and field capacity could be obtained.

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LIST OF ABBREVIATIONS, UNITS AND SYMBOLS

ANOVA	Analysis of Variance
ABU	Ahmadu Bello University Zaria
DMRT	Duncan Multiple Range Test
SAS	Statistical Analysis Software
RCBD	Randomized Complete Block Design
IAR	Institute of Agricultural Research
CPN	Planter Capacity
Kg	Kilogram
g	grams
Kw	Kilowatt
m	Meters
cm	centimeter
ha/h	Hectare per hour
h	Hour
ha	Hectare
A	Area
m^3	Meter cube
rpm	Revolution per minute
N/m^2	Newton per meter square
mm	Millimeter
^{0}	degree
%	Percentage

ω	Omega, angular velocity
θ	Theta, Angle of repose
ρ	Rho, Density
V_P	Speed of Planter
S_r	inter row spacing

CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

Planting is one of the basic and most important operation in crop production. Improvement in the planting techniques could ensure adequate establishment of uniform crop stands and make subsequent operations more effective and thus increase yield (Gambari *et al.*, 2017). Crop planting refers to placing seeds, broadcasting on the field surface or transplanting seedlings in the cultivated farmland (Ojha and Michael, 2010). The basic objective of sowing operation is to put the seed in rows at desired depth and intra-row spacing, cover the seeds with soil and provide proper compaction over the seed (Kyada and Patel, 2014). This operation is usually carried out after tillage operation and it is achieved by machinery called planters and/or seeders.

A multi rows planters sow in more than one planting row at a pass. Examples of such planters could cover two rows, three rows or more depending on the design and targeted power source. Planters may be powered using human effort, work animal, self-propelled engine and tractors power (Murray *et al.*, 2006). Example of work animal used in powering planter include cow, donkey, horse, camel. Philip *et al*. (1988) reported that the use of animal technology for agricultural practices is potentially useful and is also an appropriate means of improving the efficiency of the traditional farming system. Animal traction would increase crop yield through better and timely cultivation and planting. It would reduce labour requirement per unit area and allow an increase in the area under cultivation. It would also help resolve bottleneck in weeding and reduce the drudgery of manual labour (Hailu, 1990).

The use of animal drawn planter using donkeys is a low –cost implement and adapt well in dry area (Simalenga and Joubert 1997), it is also suitably modified for sowing and speedy weeding operations for use in light–textured soils (Awadhwal, 1991). As labour cost of account for over 70% of the total cost of production in most farming operations in rural setting (Arene, 1995), the search for an alternative source of farm power which will be cheap and affordable to the farmers therefore, became necessary (Tarig *et al*., 2013).

In order to avoid thinning, irregular plant population density which may affect subsequent operation, results in poor plant establishments, growth and low yield, the need for an animal drawn precision planters using pair of bull that are affordable, readily available, durable and indispensable. Planter are machines that ensure uniformity of seed placement including seed spacing uniformity, seeding depth precision and alignment of the seedling in the row. Thus, precision method of planting which eliminate thinning and hand labour is needed. Any of such methods must ensure a consistently high seedling emergence under the variety of microclimate and soil condition which are encountered from year to year during planting period Murray *et al* (2006).

1.2 Statement of the Problems

The planting operation in Nigeria is still characterized by direct labour input resulting non-uniformity of intra-row spacing and depth of plant, low rate of seed emergence and losses due to seed scattering (Upahi 2017).

As our population continues to increase, it is necessary that we produce more food. However, most small and medium scale farmers in Nigeria still practice traditional manual planting methods which is tedious, time consuming, requiring several man – hour per day. This causes delay in planting operation which is detrimental to the yield of crop. Isiaka *et al.*, (2001) noted that timeliness in sowing helps in taking full advantage of the soil moisture.

The locally developed planters are challenged with the inability to effectively plant on both ridged and flat land, covering a wider area in one pass (Abubakar, 1994) and seed placement at required distance and depth. These planters are equally affected by seeds metering with little seed damage, starting stress and the exhaust released from the engine propelled planters which affect their field capacities and efficiencies.

The tractor drawn planters is out of reach of financial capability of the peasant farmer (Isiaka,*et al.*, 2000) and lack of technical know – how to operate and maintain the equipment (Isiaka,*et al.*, 2001). Lack of after sale service such as provision of spare parts to replace worn – out and break down parts. Some of the modern equipment are generally not suitable nor economical for small plot sizes and often – fragmented farm land as obtains in our farming system (Mandal *et al*., 2013).

1.3 Aim and Objectives

The aim of the study is to develop an efficient four - row animal drawn precision seed planter.

The objectives are to:

i. design a four-row animal drawn precision planter.

ii. construct the planter components and assemble the prototype.

iii. evaluate the performance of the planter using maize as the test crop.

1.4 Justification

Increases in crop yield, cropping reliability, cropping frequency and crop returns depend on uniform and timely establishment of optimum plant populations (Murray *et al*., 2006). This is subject to good planting operation. To establish crops over a wide range of area in a desired position to save cost and time, a planting machine that is capable to open a furrow, meter seed, deliver and place seed appropriately in the furrow, cover the seed and firm the seedbed is used (Murray *et al.,* 2006). To this effect, developed planting equipment have proved to be more efficient and effective, however the technology for their use has to be reduced to the level of the local farmer.

As local peasant farming is about 90 % dominant of the country's system of farming (Nwuba, 1986), the desire for increase food production necessitates that the scale of production must be increased. This increase would be brought about by mechanization practice. Currently, Nigeria has abundant animals which could be adopted to power our implements in farming operation. Also, the increase in scale of production subsidizes the cost of using the locally made and imported tractor drawn planters as buying or hiring of tractor is required. In regards to the problems stated above, there is need to develop a planter that will eliminate the limitations associated with; manual planting method, locally developed planters (manual / tractor drawn type), imported tractor drawn planters as well as increasing the field capacity of the planting operation. This research intends to bridge this gap by developing four - row animal drawn precision seed planter using a pair of work Bulls.

1.5 Scope and Limitations

The scope of the research work covers the design of a four-row animal drawn precision seed planter; fabricating and assembling the component part as well as; evaluating the developed planter. The limitations in this research work included:

i. The field evaluations were done during the rainy seasons of the years. There was the limitation of having equal amounts of soil moisture content at the testing periods in the subsequent years.

ii. The types of soil to be tested on is to have same composition and consistency. There was the limitation of non-consistency of the soils

iii. The type of crops required to be used during evaluation should not exceed 10 mm as the maximum seed cell diameter was only 13 mm. There was limitation of using only graded seeds.

iv. There was limitation on using a well-behaved animal controller and well-trained pair of bulls.

CHAPTER TWO

LITERATURE REVIEW

2.1 Agronomic Requirements for Crop Establishment and their Influence on Planting

For planting to be agronomically proficient, certain physical requirements must be accomplished aside the in-situ soil condition. There are agronomic requirements for germination, for emergence and for crop establishment. The agronomic requirements for germination includes seed factors (seed quality and pre-sowing treatments on the seeds) and environmental factors. These have implications on planter performance (Murray *et al*., 2006).

The implications of the agronomic requirements for germination on aspects of planter performance are:

2.1.1 Seed factors

Seed quality has major implications for seed metering devices. Substantial increases in planting rate to compensate for low seed viability can impair the performance of seed meters, particularly precision seed metering devices (Norris, 1982; Halderson, 1983 as in Murray, 2006). Variations in seed size and shape can also influence planter performance. Some precision seed metering systems (e.g. plate type) require uniformity in both size and shape for optimum performance; others (e.g. vacuum disc type meters) will tolerate a range of seed size and shape without a significant reduction in metering performance (Zulin *et al*., 1991). Norris (1982) concluded that:
i. seed damage increases with meter speed and/or seed size;

ii. Seed metering performance is reduced as meter speed and/or seed size increases and

iii. The maximum recommended operating speed of vacuum and finger pick-up units severely limits operating speed when planting large seeds, such as peanuts, at the recommended spacing. Pre-sowing seed treatments can improve or impair seed metering performance (Norris 1982).

2.1.2 Environmental factors

Planter soil-engaging components have a major influence on optimizing environmental factors for germination. To optimize moisture availability to the germinating seed, the planter must open a furrow, place the seed in the furrow, cover the seed and firm the seedbed. Opening a furrow enables the seed to be planted at a depth where moisture conditions are generally more favourable than those at the soil surface. It is of particular importance in regions where high evaporation rates after rainfall promote rapid drying of the surface layer (Maiti and Carrillo-Gutierrez, 1989 as in Murray 2006). Covering the seed and firming the soil around it helps to stabilize temperature and moisture availability conditions, and protects the seed from predators such as birds and ants. The degree of soil disturbance in the seed zone during the furrow opening process has a major influence on moisture availability to the germinating seed. The nature and degree of disturbance is largely a function of furrow opener design (Dickey *et al*., 1994). When crop establishment is the first priority. The degree of disturbance should be restricted to that necessary to obtain sufficient tilt to help cover the seed and ensure sufficient seed/soil contact. Opener design should be such that the seed is placed in or on the moist soil at the base of the furrow and dry soil is not placed immediately on the top of the seed during the covering phase.

The implications of the agronomic requirements for emergence on aspects of planter performance are:

2.1.3 Control of planting depth

Planting depth is a major determinant of seedling emergence and hence one of the most important operational requirements of a planting machine (Rainbow *et al*., 1992). Inadequate depth control accuracy is recognized by farmers and researchers as a major deficiency of planting machines. Providing planting machines capable of maintaining uniform depth under field conditions is a major challenge for equipment designers. Optimum planting depth has two essential components: the depth of the furrow relative to the original soil surface and the depth of soil covering the seed. The depth from the original soil surface has implications for the level and likely duration of moisture availability to the seed. The depth of soil cover over the seed has implications for emergence. The implications of the agronomic requirements for establishment on aspects of planter performance are (Kepner *et al*., 1987):

2.1.4 Plant competition

Competition between plants for water, nutrient and light resources has important implications for establishment. Time of seedling emergence has the largest effect when the spread is large, the seedlings have a high relative growth rate, the plant density is high and growth to harvest time is short (Benjamin 1990)

2.1.5 Plant population and spacing requirements

The primary objective of any planting operation is to establish an optimum plant population and spacing. Factors other than yield are sometimes of considerable importance in establishing the best population and/or spacing for a particular crop. Plant spacing is usually by specified inter row and intra row for every variety of the crop. The plant population (i.e. the number of established plants/ha) influences the degree to which competition influences crop establishment. Many factors have to be considered when determining the optimum population and the spacing (i.e. the distance between rows of plants and the spacing of plants within a row) for a particular crop. Row spacing may affect the ease of inter-row cultivation and harvesting. Populations and row spacing may affect weed growth and control (Wollin *et al*., 1987)

Table 2.1: Detail for Planting Seed by (Kyada and Patel, 2014)

Vegetable	Distance between plants(cm)	Planting depth (cm)
Asparagus	30	2.5-4
Beet	3-5	1.5
Broccoli	45-60	0.5-1.5
Cabbage	45	0.5-1.5
Carrot	3-5	1.5
Cauliflower	45-60	0.5-1.5
Corn	15-25	2.5
Okra	30	2.5
Onion	5-8	1.5-3
Pepper	60	1.5
Potato	25-30	10
Radish	2.5	1.2

2.2 Planter Functional Requirements for Crop Establishment

To successfully establish crops over the range of conditions likely to exist at planting; a planter should be able to open a furrow, meter the seed, deliver the seed to and place the seed appropriately in the furrow, cover the seed in the furrow, firm the seedbed and perform other functions as required e.g. weed control, apply crop chemicals, etc. These functions must be performed at an acceptable forward speed and with a high degree of reliability. Not all planting machines are capable of performing or necessarily need to perform all the functions. Nevertheless, the ability to perform all functions improves planter flexibility and crop establishment prospects, particularly when sub-optimal crop establishment conditions exist at the time of planting. The functions performed by the planter's soil-engaging components and its seed metering and distribution system largely determine its overall performance under particular conditions. The planter functions undertaken by the soil-engaging components include those associated with opening the furrow, covering the seed and firming the seedbed Murray *et al* (2006).

2.3 Classification of Planters

The planting machinery can broadly be classified on the basis of a combination, where applicable, of; the number of rows planted in one pass of the machine, the method of attachment to and the type of power source used to propel the machine and the planting pattern (Murray *et al*., 2006). These machines can be classified as single row, four row, forty row, depending on the number of furrow openers. On multi-row machines, the furrow openers are typically uniformly spaced across the full width of the machine. On the basis of the power source used to provide the draft, planters can usually be classified as; Human (hand-held, pulled or push), Animal (pulled) and Tractor-powered (trailed, semi-mounted, front/mid/rear mounted). Planters' type with respect to their planting pattern are classified as; broadcast planter, drill planter, dibble planter and precision planter as shown in Plate 2.1, 2.2, 2.3 and 2.4 respectively.

Plate 2.1: Broad cast planter (Murray *et al.*, 2006)

Plate 2.2: Drill planter (Murray *et al.*, 2006)

Plate 2.3: Dibble planter (Murray *et al.*, 2006)

Plate 2.4: Precision planter (Murray et al., 2006)

Animal drawn precision planters obtained their power through the horizontal component of the force by pull provided by the draught animal and accurately place single seeds or groups of seed almost equidistant apart along a furrow. They are typically used to plant crops that require accurate control of plant population, and spacing between and along the rows. Crops in this category include almost all the horticultural crops and field crops such as sorghum, maize, sunflower, soybeans and cotton. Precision seed metering systems giving a precision drill, hill drop or check row planting pattern are used on this type of planting machine.

2.4 Existing Planters

Developed planters with various performance levels were reviewed. Various planters which include animal drawn, self-propelled, manual type and tractor mounted planters are discussed in this chapter.

2.4.1 Animal drawn planters

Isiaka *et al.* (2000) developed a two-row animal drawn planter which uses seed metering cells that drive their power from the traction wheel through a gear arrangement. The planter was tested in both laboratory and field condition to evaluate its performance using maize seed 0.82 m/s, the result obtained for seed rate, seed damage and hill distance were 15.50 kg/ha, 0.8 % and 36.55 cm respectively. The field capacity, field efficiency and average required draft to pull the planter were also 0.44 ha/hr., 85 % and 978 N respectively.

Isiaka *et al.* (2001) compared the effectiveness of the two-row animal drawn planter shown in plate 2.5 below with manual planting method under ridged and flat cultivation systems. The result showed that the field capacity for double row animal drawn planter is twice the single row animal drawn planter and about eight times that of manual planting method. The plant to plant spacing and seed placement depth were uniformly placed with the animal drawn planter than the manual planting.

Plate 2.5. Two rows animal drawn seed Precision Planter (Isiaka *et al.* 2000)

Mandal *et al.* (2013) fabricated an Animal drawn multipurpose agricultural planting equipment which was designed and was developed at CSIR-Central Mechanical Engineering Research Institute (CMERI) Durgapur, West Bengal, India for planting of suitable crops. The performance was studied with a pair of buffalo to draw the implements throughout the experiment. The result showed that the equipment works at an average speed of 0.8m/s for 8h a day. The average field capacity was observed as 0.27 ha/hr for the three varieties of crop used.

Plate 2.6: Multipurpose animal drawn planter (Mandal *et al* 2013)

Tarig *et al.* (2013) evaluated the effect of animal drawn planter on establishment and yield of groundnut in sandy soil. In this experiment, two types of sowing methods were used, the animal drawn planter and manual sowing. The animal drawn planter is simple, locally made and easily operated and maintained by farmers. The treatments were arranged in randomize plots with three replicates and analyzed by t-test. The parameters observed were sowing time, plant population, depth of sowing, uniformity %, weeding %, 50% flowering; and yield and hay production. The results showed that there were highly significant differences between the animal drawn planter and manual planter for a parameter such as time for sowing, sowing depth, plant population, uniformity of seeding, in groundnut cultivation weeding efficiency, seed and hay yield (kg/ha). The animal drawn planter saves sowing time by 86.6 % compared to manual sowing. It also gave better crop establishment, distribution and uniformity of plant population which resulted in higher yield (1583.9kg/ha) than that of manual treatment (998kg/ha). The results of the economic analysis revealed that the animal drawn planter sowing recorded the highest net return and marginal rate of return (92%) compared to manual sowing for groundnut under rain-fed condition.

Plate 2.7: Single row groundnut animal drawn planter (Tarig *et al*., 2013)

FAO (2000) reported that the draught animal can produce tractive effort equal to 1/10th of its body weight for a period of 10 hours in a day, for short duration of time, more pull could be developed at lower speed too.

Yadhav (1990) studies on draught capacity of Malvi and local breeds of bullocks and he has concluded that the weight of bullock was directly responsible for their draught capacity. It was also concluded that Malvi pairs could exert more draught as compared to local breeds of bullocks due to their heavy weight. The maximum output from bullocks could be produced during winter season due to comfortable ambient condition. Animal could work up to a 14 % load for six hours, a rest pause of one hour in between. It was also concluded that on the basis of average energy output of the whole day, working a load equivalent to 10 % of body weight with a rest pause of one hour in two session of working was found better.

ILO (1986) found that most of the animals could exert a draught of 10- 14 per cent of their body weight while working at a speed of 2.5 to 4.0 km/hr (i.e. 0.6 to 1 m/s). The duration of work that an animal would sustain their normal tractive effort was considered important in determining the effectiveness as power source for transport.

Rahama and Hussein (1993) designed, developed and tested an animal drawn implement to perform both ploughing and seeding on clay soils. A seeder with a simple metering mechanism and a gauge wheel provided a system for the seeds to be placed at spacing as required by the crop. Experimental work proved its significant labour-saving capacity, which could be made of use in the peak times to meet timely requirements of land preparation.

2.4.2 Self-propelled planters

Upahi (2017) developed and carry out performance optimization on a two – row engine – propelled seed ridge planter shown in plate 2.5 below. The planter has two hoppers, two seed metering units, two delivery chutes, two coulters, two soil covering devices and a drive mechanism. The evaluation of the machine was in term of planting speed, seedling emergence, plant to plant spacing, energy expended, seed delivery rate, number of seed per hill and seed damage. The result for the seed delivery rate was 19.8 kg/ha, effective field capacity of 0.22 ha/hr, field efficiency of 70.71 %, average planting speed of 0.55 m/s, average plant spacing of 25.9 cm and least expended energy of 261.82 MJ/ha.

Plate 2.8. Two rows engine propelled seed ridge planter (Upahi 2017)

Matin *et al*. (2008) developed and evaluated a multi-crop power tiller operated Inclined Plate Planter (IPP) for the establishment of maize. The planter was evaluated against traditional practice of planting in Bangladesh. It had an average field work rate capacity of 0.19 ha/hr saving 3.28 % total cost and 79.2 % labour cost. It had 18 % increases in yield.

Celik *et al.* (2007) evaluated four different type seeders for seed spacing, depth uniformity, and plant emergence at three forward speeds (3.6, 5.4 and 7.2 km/h). The planter types were: no-till planter, precision vacuum planter, universal planter, and semi-automatic potato planter. Uniformity of planting depth of seeds was described using the mean, standard deviation and the coefficient of variation of the sample methods. Plant emergence ratios were evaluated by mean emergence time, emergence rate indexes, and emergence percentage.

Adisa and Braide (2012) designed and developed a template row planter to improve planting efficiency and reduce drudgery involved in manual planting method. They also recorded that the row planter increased seed planting, seed/fertilizer placement accuracies and it was made of durable and cheap material affordable for the small-scale peasant farmers. The operating, adjusting and maintaining principles of the planter were made simple for effective handling by unskilled operators (farmers). The field capacity of the template row planter was found to be

0.20 ha hr-1. Template seed filling efficiency was found to be 88 % and draft requirement was found to be 85 N at average speed of 2.16 km hr^{-1}.

2.4.3 Manual planters

Ibukun *et al.* (2014) design and fabricated a manually operated single row maize planter capable of delivering seeds precisely in a straight line with uniform depth in the furrow, and with uniform spacing between the seeds. The results obtained from the trial tests showed that the planter functioned properly as expected with a field capacity of 0.0486 ha/hr. Visual inspection of the seeds released from the planter's metering mechanism showed no visible signs of damage to the seeds.

Soyoye *et al.* (2016) designed a manually operated vertical seed-plate maize planter with 89.7 % efficiency and 1.53 ha/hr planting capacity.

Oduma *et al* (2014) developed a manually operated cowpea precision planter under laboratory and field investigation. The planter effectively metered out two seeds per discharge at an average planting depth of 2.22 cm and minimum seed damage of 2.34 %, the field efficiency and capacity were 71.71 % and 0.26 ha/hr respectively.

Nwachukwu and kuye (2000) developed single row seed planting machine. The machine was A simple and low cost prototype seed planter was designed, constructed and tested. The materials used for construction are mild steel and wood. The test crop was cowpea with expected distribution of 2 seeds per drop at 25cm spacing. The test result shows an average of 2 to 3 seeds per hole at average spacing of 25.2cm. The field capacity is 0.1036ha/hr at 0.75 m row spacing while the seed rate is 26.81kg/ha. Optimum planting efficiency of 58% was found at operational working speed of 0.6m/s. the germination percentage of planted seeds was 52%.

2.4.4 Jab planters

Abubakar (1994) developed a manually operated multi crop (maize, cowpea and groundnut) rotary jab planter for sandy loam soils under field and laboratory test. The field performance revealed slightly different result due to the effect of the soil moisture content and planting speed and the result for the mixed cropping germination count, placement depth and seed spacing were 88.07 %, 3.79 cm and 35.30 cm respectively. While the result obtained from the laboratory for discharge rate and seed spacing were 24.28 kg/ha, 18.05 kg/ha, 41.01 kg/ha, 25.04 cm, 23.12 cm, and 37.54 cm respectively.

2.4.5 Tractor drawn planter

Agidi *et al* (2017) developed a tractor drawn Soybean drum planter and tested in the DESFABENG Company Limited, Bida, Niger State. The project was undertaken due to the fact that most of the imported planters usually have maintenance and repair problems in addition to high costs of procurement that are not affordable to an average farmer. The major components of the developed planter are three drums with predetermined hole sizes at the exterior ends, a central rectangular shaft, spring soil openers, roller soil coverers, tractor hitching points, two wheels and power transmission mechanism and frame. All these components were fabricated with locally available materials. Using three test speeds, the planter was preliminarily assessed for seed rate, soil opening, covering and germination efficiencies. Results obtained indicate that desirable seed rate values of 47.7 and 61.2 kg/ha were observed for tractor/implement speeds of 20 and 16 km/hr, respectively. The highest germination efficiency of the planter was 81.3% at tractor/implement speed of 16 km/hr with corresponding soil opening efficiency of 94%.

2.5 Planter Metering Mechanism

Planter metering mechanism is a key component of planters that directly affect crop development and yield based on the performance of the particular design. A wide range of seed metering devices exist, but most can be classified as either precision or mass flow type, depending primarily on their principle of operation and the resulting planting pattern (murray *et al*., 2006). Mass flow types do not meter individual seeds but rather a consistent volume of seeds per unit of time to give the average desired seed spacing. They are therefore used for crops that are usually planted at higher seeding densities (150 -1500 seeds/m^2); planted in relatively narrow rows (80–350 mm); and for crops (such as cereal grains and grass pastures) that can tolerate considerable variation in both seeding rate and uniformity of seed spacing without a significant loss in yield (Townsend *et al*., 2011). Mass flow seed metering systems are used on planters generally referred to as broadcast, drill and air seeders and can be broadly classified as either stationary opening, external force feed (fluted and peg/studded rollers) and internal force feed (double run) types (Murray *et al.*, 2006). Precision seed metering systems are generally used on row crop planters and for metering single seeds (Khan 2008). Depending on the design and/or shape of the principal moving element that enables selection of single seeds from the seed lot, precision metering devices can be broadly classified as plate, belt, disc, drum or finger types (Jayan *et al*., 2004). Plate planters are those that principally use a moving plate with indents, i.e. holes, cells or cups, around its periphery and metering performance is generally highly dependent on matching the size (length, breadth and thickness) of the indents to the size of the seed. Plate meters can be sub-classified as horizontal plate, inclined plate or vertical plate types (Murray *et al.*, 2006). Previous research effort suggested that plate metering system would be suitable for maize seeds (Gray *et al*., 2012).

2.6 Research Gap

This research reviewed studies related to the designs, fabrications and performance evaluations of seed planters, the seeds include maize, cowpea, and soya beans, the literature indicate that most of these planters were powered manually, animals, prime movers and tractors yet characterized with inability to precisely place seeds at required distance and depth, complexity in operation and maintenance. As research on seed planters is more prominent using a pair of bull. Therefore, this research focused on the Development and Performance Evaluation of a Four Row Animal Drawn Precision Seed Planter to solve the above difficulties.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Materials

3.1.1 Selection of materials for construction

The materials were selected based on strength, availability, durability, cost effectiveness, and suitability. These materials were 50 mm × 50 mm mild steel angle iron, gauge 16 and 18 mild steel sheet metal, 3 mm × 50 mm flat bar, 25 mm round mild steel bar, 25 mm diameter bearing, Black Afara wood plank 40 mm in thickness and 193 mm in diameter.

3.1.2 Instrumentations

The instrument used for the determination of the design related seed properties and field evaluation were; 5 kg capacity electric weighing balance, 150 mm digital sharp edge Vernier caliper, 60 minute Casio stop watch, 100 m steel measuring tape, 300 mm plastic ruler, 300 mm long wooden peg.

3.2 Determination of Design Related Seed Properties

SAMMAZ 14 variety of maize was obtained from Seed Production Unit, Institute of Agricultural Research (IAR) for the experiment. 1000 grain of the seed was randomly picked for the determination of size, shape, coefficient of friction, moisture content, angle of repose as prescribed by FAO (1994). These was achieved using the procedure outlined as follows.

3.2.1 Determination of seed sizes

The length, diameter and thickness of the maize seed was determined using 150 mm digital sharp edge Vernier caliper as shown in Appendix B. Hundred samples were selected randomly from the bulk of 1000 maize grain obtained from the IAR Seed Production Unit. The seed was then taken to the laboratory for the size determination as mentioned above.

3.2.2 Determination of seed angle of repose

A funnel with a wide outlet was affixed at a distance of 100 mm above a flat surface where a piece of paper was placed on the surface. The maize seed sample collected in a separate container was then poured gradually in the funnel allowing the content to flow through and accumulate on the paper placed on the flat surface to form a conical heap. The height and diameter of the heap was measured (Maduako and Hannan, 2004). This procedure was repeated three times and the angle of repose was calculated using equation 3.1

$$\theta = \tan^{-1} \left(\frac{2H}{D}\right) \qquad (3.1)$$

Where θ = angle of repose (^{o})

H = height of the heap (mm)

D = Diameter of the heap (mm)

3.2.3 Determination of seed coefficient of friction

Appendix B shows the result of the coefficient of friction of the seed which was determined on plywood, plastic and steel sheet metal surface using a tilting table. The seed sample was poured on the squared flat material (i.e. plywood, plastic and steel sheet) one after the other, the material was then tilted from one side, as soon as the seed sample on the flat material begin to slide down, the angle of inclination of the material 'α' is then measured. This is in line with the procedure adopted by Maduako and Hannan (2004). Coefficient of friction was determined by the following equation.

$$\mu = \tan \alpha \qquad (3.2)$$

Where μ = coefficient of friction (unit less)

α = angle of inclination of the table to the horizontal (^{o})

3.3 Design Calculation of the Machine Component

3.3.1 Design consideration

The seed planter was designed and constructed by considering the following factors;

i. Simplicity in design, construction, operation and maintenance.

ii. A well designed four units to increase the field capacity.

iii. Suitability for different seed crops with a corresponding graded seed shape and sizes

iv. Use of locally available materials with high durability and low cost.

v. Rigidity of the machine to withstand the various working stress in the field.

vi. Use of pair of bull as a source of power for moving the planter.

vii. Accurate and uniform placement of seeds in a desirable distribution pattern and depth without damage;

viii. Circular Black Afara wooden plate having 6 numbers of U- shaped cells made on the circumference of the metering device was considered

3.3.2 Hopper design parameters

The seed hopper was made of mild steel sheet of 1.5 mm thickness. The seed box is rectangular in shape at the top but tapered towards the bottom at an angle of 72^o forming a hollow trapezoidal shape with bottom base area of 60 mm × 40 mm and top area of 230 mm × 200 mm and height of 250 mm as shown in Appendix A2 and A3. The angle is chosen to be greater than the angle of repose of the seed grain used and as such it assists in self – empty of the grain into the metering mechanism Micheal (2014).

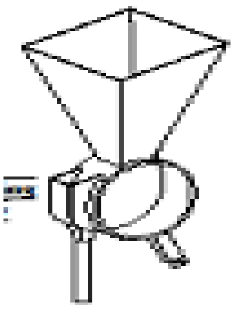

Figure 3.1: Schematic diagram of the hopper

3.3.2.1 ***Hopper capacity***

The hopper capacity is the number of seeds or quantity of seeds the hopper could bear. Hopper capacity was determine using equation (3.3) by Soyoye *et al* (2016).

$$H_c = \frac{TVH}{AVS} \tag{3.3}$$

Where H_c = Total number of seed in the hopper

TVH = total volume of the hopper

AVS = average volume of seed

TVH = 0.00365 m^3

The volume of an average grain could also be determined using the Equation given by Jain and Bal.(1997) as;

$$AVS = 0.25[(\frac{\pi}{6})\ L\ (W+T)^2] \tag{3.4}$$

Where; *L*= length of the grain

W= width or breadth of the grain

T= grain’s thickness.

$AVS = 0.00000022\ m^3$

$H_c = 17232$ seeds

At 90 % hopper capacity, a total of 15509 seeds was obtained. For the four hoppers, a total of 62036 seeds was computed.

3.3.3 Determination of number of cells

Provided the speed ratio between the traction wheel and the metering plate is one, the number of cells could be determined using the expression below given by Ibukun *et al*. (2014)

$$\text{Number of cells} = \frac{\pi \mathrm{dw}}{S_c} \tag{3.5}$$

Where d_w = diameter of the planter ground wheel

S_c = intra row spacing of the seed

The wheel diameter of 477.4 mm and intra row (IAR) recommended spacing of 250 mm was used. Therefore, the number of cells on the metering plate was 6 holes.

3.3.4 Determination of angle of inclination for the planter handle

The angle of inclination for the adjustable planter handle may be determined using Equation 3.6 (Kalay *et al*,2015)

$$\text{Tan}\theta_h = \frac{h1}{h2} \tag{3.6}$$

Where θ_h = angle of inclination

h_1 = height of Centre of wheel to the controller elbow

h_2 = horizontal distance between the normal to the wheel and normal to the elbow

3.3.5 Weight of the planter

Weight of the planter component acting on the wheel = $W_m + W_h + W_{fr} + W_c + W_b + W_{ala}$ (3.7)

Where W_m = Weight of the metering plate (1.11 kg)

W_h = Weight of the hopper (1.68 kg)

W_{fr} = Weight of the frame (7.85 kg)

W_c = Weight of the metering casing (1.74 kg)

$W_b = W_{hsp} + W_g$

W_b = weight of connecting bar (16.08 kg)

W_{hsp} = weight of hollow square pipe (6.92 kg)

W_g = weight of gravel (9.17 kg)

Then the weight of single planter was computed as 12.38kg. Considering four row planter with the connecting bar, the net weight is 65.60kg.

$$W_c = \ell \times V \times g \tag{3.8}$$

Where W_c = weight of components

ℓ= density of the material

V = volume of the material

But $\ell_m = 960 kg/m^3$ $\ell_h = \ell_{fr} = \ell_c = \ell_b = 7850\ kg/m^3$ $\ell_g = 1346\ kg/m^3$

Where ℓ_g = density of gravels = 1346 kg/m^3

$V_m = \pi h\ (R^2 - r^2) = 0.001151\ m^3$

$V_h = 2 \times (A_l \times t + A_s \times t) = 0.000214\ m^3$ (Bronshtein *et al*., 2015)

Where A_l = area of the large plate of the hopper (m^2)

A_s = area of the small plate of the hopper (m^2)

t = thickness (m)

Area of the hopper plate (A) = $2[\frac{1}{2}(a_l + b_l)h] + 2[\frac{1}{2}(a_s + b_s)h]$ (Bronshtein *et al*., 2015)

Where a_l = length of the small side of the large plate

b_l = length of the large side of the large plate

a_s = lengtjnbh of the small side of small plate

b_s = length of the large side of the small plate

h = height of each plate

$$V_{fr1} = V_l + V_b \quad (3.9)$$

$$V_{fr1} = 2[L_l(2B_l)T_l] + 2[L_b(2B_b)T_b] \quad (3.10)$$

$V_{fr1} = 0.000295656\ m^3$

$V_{fr2} = 2[L(2B)T] = 0.00018288\ m^3$

$V_{fr3} = 2[L(2B)T] = 0.00012192\ m^3$

$V_{ala} = 2[L(2B)T] = 0.0006096\ m^3$

$V_{fr} = V_{fr1} + V_{fr2} + V_{fr3} + V_{ala} = 0.001210056 m^3$

$V_{fr} = 0.001\ m^3$

$V_c = \pi R^2 h - \pi r^2 h = 0.000222\ m^3$

$V_c = 0.000222\ m^3$

$W_b = W_{hsp} + W_g$

$V_{hsp} = 0.000881484\ m^3$

$V_g = 0.0068088232\ m^3$

$V_b = 0.000881484 + 0.0068088232 = 0.0144991304\ m^3$

3.3.6 Total torque

The total torque here is the sum of the torque from the traction wheel and the metering plates.

$$T = T_w + T_m \tag{3.11}$$

Where, T_w = torque on the wheels (1192.68 Nm)

T_m = torque on the metering plates (4.184 Nm)

The total torque is computed as 1196.862 Nm.

3.3.6.1 ***Determination of the torque on the metering plate***

The torque on the metering plate is obtained below

$$T_m = F_{md} \times r_{md} \quad (3.12)$$

Where F_{md} = force produced by the metering plate

r_{md} = radius of the metering plate

$T_m = 1.046$ Nm

For the four metering plates we have $T_m = 4.184$ Nm

3.3.6.2 ***Draft requirement for the planter***

$$\text{Total Draft requirement for the planter} = D_f + D_w \quad (3.13)$$

Where D_w = draft on the wheel

$$D_f = R_s \times A_f \times g \quad (3.14)$$

Where D_f = draft of the furrow opener

R_s = soil resistance

A_f = area of the furrow opener

g = acceleration due to gravity (9.81 m/s^2)

Considering 1.5 cm soil depth

$D_f = 135.97$ N

For the four planter $D_f = 543.88$ N

3.3.6.3 ***Force required to overcome soil resistance***

$F_{rs} = R_s \times A_c \times g$ (3.15)

Where R_s = soil resistance

A_c = contact area of the wheel

F_{rs} = 28.78 N

For the four planter F_{rs} = 115.12 N

3.3.6.4 ***Rolling resistance of the wheel***

$R_r = (\frac{1.2}{c_n} + 0.04)W$ (3.16)

But $c_n = \frac{CI \times b \times d}{W}$

Where W = total force/load exerted on the wheel (N)

CI= cone index (N/m^2)

b = width of the wheel (m)

d = depth of the wheel in the soil (Schreiber and kutzbach, 2008)

Considering cone index for heavy clay soil which is 0.735 kg/cm^2, wheel depth of 1.5 cm and the wheel width (b) to be 5.08 cm

$c_n = \frac{CI \times b \times d}{W}$ (3.17)

c_n = 0.18

R_r = 1084.39 N

For the four planters = 4337.56 N

3.3.6.5 *Total forces required to pull the planter*

Total Force (F) = $D_{fr} + F_{rs} + R_r$

Where D_{fr} = Draft of furrow opener

F_{rs} = Force required to overcome soil resistance

R_r = Rolling resistance of the wheel

F = 4996.56 N

3.3.6.5 *Torque on the wheel*

$T_w = F \times r_w$ (3.18)

Where r_w = Wheel radius

T_w = 1192.68 Nm

3.3.7 Power required to pull the planter

The power required to push the wheel of the planter is determined as expressed below (Khurmi and Gupta 2005);

$$P = T \times w \tag{3.19}$$

Where P= power required to push the planter

T = torque on the shaft (1196.862 Nm)

w = angular velocity (0.105 rad/sec)

The power required to push the planter per revolution is calculated as 125.67 W.

3.3.8 Determination of the shaft diameter

The shaft size was selected using the relationship given by Hall and Hallowenko (1982) as;

$$d^3 = \frac{16}{\pi\tau_s}\sqrt{(K_b M_b)^2 + (K_t M_t)^2} \quad (3.20)$$

Where; d = shaft diameter

K_b and K_t = combine shocks and fatigue factors applied to bending and torsional moment respectively

M_b and M_t = bending and torsional moment (N/m^2)

τ_s = allowable stress of the steel shaft (N/m^2)

Allowable shear stress for shaft without keyways, τ_s = least value of 0.3 yield strength and 0.18 ultimate strength of the shaft material (Khurmi and Gupta 2005)

The material selected for the shaft is mild steel (C1040) with ultimate and yield strength of 770 and 580 MN/m^2 respectively.

$0.3(580) = 174\ MN/m^2$

$0.18(770) = 138.6\ MN/m^2$

The smaller value is $138.6\ MN/m^2$ and further reduced by 25 % due to the presence of key way

$(1-0.25)138.6 = 103.95\ MN/m^2$

Allowable shear stress for shaft, $\tau_s = 103.95\ MN/m^2$

K_b = 1.5 to 2.0

And K_t = 1.0 to1.5

$d^3 = \frac{16}{\pi \times 103.95 \times 10^6}\sqrt{(1.5\ \times 0.0006)^2 + (1.0\ \times 299.22)^2}$

$d_s = 0.0253$ m

$d_s = 25.3$ mm

Therefore, a shaft of 25 mm diameter was selected.

3.3.9 Determination of seed population

The seed population was determined by using equation as reported by Soyoye *et al.* (2016)

$$P_s = n[\frac{A}{SrSc}] \quad (3.21)$$

Where P_s = actual seed population

n = average number of seed discharge per hole

A = area of the field

S_r = inter row spacing

S_c = intra row spacing

With n = 1 seed, A = 2.25 × 5 m, S_r= 0.75 m, S_c = 0.25 m (Ameyu., 2020)

Then P_s = 20 seed for a single planter along 5 m length with 0.25 m intra row spacing.

3.3.10 Field capacity

The capacity of the planter in terms of area per time may be obtained from the below expression as reported by Soyoye *et al.* (2016);

$$P_c = \frac{A}{10^4} \text{ (ha/hr)} \quad (3.22)$$

$A = S_r \times V_p$ (m^2) / hr

Where P_c = planter capacity in ha/hr

S_r = inter row spacing

A = area covered by the planter

V_p = speed of the planter.

When planting at a speed of 3.6 Km/hr (1 m/s), 2.88 Km/hr (0.8 m/s) and 2.16 Km/hr (0.6 m/s) from literature findings.

P_c = 0.59, 0.56 and 0.33 ha/hr respectively.

The capacity of the planter in terms of number of seeds planted per time was obtained from the following expression;

$$CPN = \frac{V_p}{S_c} \times N_s \text{ (seeds / time)} \qquad (3.23)$$

Where P_c = planter capacity

A = area covered by the planter (m^2) per unit time

S_r = inter-row spacing (m)

V_p = speed of the planter (m/hr)

N_s= number of seed/holes

CPN = capacity of the planter in terms of number of seeds planted per time.

When the planter drops 1 seed at intra row spacing of 25 cm and at the same speed

CPN = 19200, 15360 and 11520seeds / hr respectively.

Table 3.1: Summary of Design Calculations

s/n	Design component	Initial Data	Design procedure	Result
1	HopperCapacity (seed/hectare)	TVH = 0.00365 m^3 AVS=0.00000022 m^3	$H_c = \frac{TVH}{AVS}$	H_c =17232 seeds/ha
2	Number of cells	d_w = 477.4 mm S_c = 250 mm	$C_n = \frac{\pi dw}{S_c}$	C_n = 6 cells
3	Seed population of a single planter	n = 1 A = 5 × 2.25 m S_r = 0.75 m S_c = 0.25 m	$P_s = n[\frac{A}{SrSc}]$	P_s = 20 seeds
4.	Planter capacity	For V_p = 1, 0.8 and 0.6 m/s N_s = n = 1	$P_c = \frac{A}{10^4 m^2}$ (ha/hr) A = $S_r \times V_p$ (m^2)/unit time CPN = $\frac{V_p}{S_c} \times N_s$ (seeds/time)	P_c=0.59, 0.56 and 0.33 ha/hr CPN = 19200, 15360 and 11520 seeds/hr
5	Power required to push the planter	T = 1196.862 Nm W = 0.105 rad/sec	P = T × w	P = 125.67 W
6	Shaft	M_t = 299.22 Nm M_b = 0.0006 Nm K_t = 1.0 K_b = 1.5 τ_s =103.95 MN/m^2 π = 3.142	$d^3 = \frac{16}{\pi \tau_s}\sqrt{(K_b M_b)^2 + (K_t M_t)^2}$	d_o = 25 mm

3.4 Description of the Planter

The planter comprised of the following components viz; hopper, frame, metering mechanism, furrow opener, delivery tube, furrow coverer, traction wheel and press wheel. The detailed description of the components of the planter are presented in Appendix A3.

3.4.1 Hopper

The hopper was made from a steel metal plate of gauge 16 (1.5 mm) forming a hollow frustum of a triangular prism with bottom base area of 60 mm × 40 mm and top area of 230 mm × 200 mm, the height is 250 mm. The hopper was designed with the consideration of the grain's angle of repose. It had a slant base which enable seeds flow through the outlet.

3.4.2 Frame

The frame is a component on which all other components are attached. The frame was made of 2 inch × 2 inch × 3 mm angle iron. The material of the main frame was selected based on weight, strength, reliability and availability of the material.

3.4.3 Metering mechanism

The metering mechanism was made of wooden disc of 193 mm diameter and 40 mm thickness. It had six equally spaced holes at the circumference of the plate, the disc was enclosed in a faced ring pipe of length 50 mm with internal and external diameter of 195 mm and 202 mm respectively. The holes (cells) pick only one seed when the disc rotates in a vertical plane at the bottom of the hopper. It is mounted on a horizontal shaft which is driven directly by the side traction wheel.

3.4.4 Furrow opener

The Furrow opener is made of 3 mm mild steel sheet with a length of 240 mm. The angle bar iron was fabricated to knife edge like structure to facilitate an easy cut through the soil and as well attached with a seed coverer made from sheet metal of same thickness which opened at an angle of 90˚. Threaded shaft is used to fasten the device to the frame through a hole drilled on the frame.

3.4.5 Delivery tube

This is a rubber syphon of 1-inch diameter and 200 mm length made from polyethylene through which the seeds metered is out and deposited into the furrow. The seed delivery tube is located below the metering casing into which the metering plate releases the seed after picking the seeds from the bottom of the hopper.

3.4.6 Connecting bar

This is a bar on which the four row planters are mounted and also adjustable for ridge spacing. The individual planter units were attached to the bar with a U-bolt through a connecting frame protruding out at an angle of 180^0. The connecting bar was constructed by welding two mild steel angle iron of 50 mm × 50 mm to form a hollow square pipe.

3.4.7 Traction Wheel

The wheel was made of a 3 mm × 50 mm mild steel flat bar cut and folded into a wheel of 477 mm diameter. Small pieces of ¾ flat bars were attached throughout the circumference of the wheel to provide lugs for effective traction.

3.5 Performance Evaluation of the Machine

The performance evaluation of the planter was carried out at both the laboratory and on the field. The procedures prescribed by FAO (2000) on testing and evaluation of agricultural machinery and equipment was adopted; the laboratory test were seed Delivery rate (kg/ha), Damage seed (%), Spacing evenness (cm). The field test were; Field efficiency (%), field capacity (ha/hr), Germination count (%), planting depth (cm). Number of seed per drop and seed delivery rate were determined at both laboratory and field. These was achieved using the procedures below.

3.5.1 Seed delivery rate R_s (kg/ha)

The seed delivery rate was determined from the formula given below. Plate 4.4 below shows the quantity of seed in kilograms per unit area of planted field.

$$R_s = \frac{Qp}{A} \tag{3.24}$$

Where Q_p = Quantity of planted seed (kg)

A = Area of planted field (ha)

3.5.2 Damaged seed D_s (%)

The percentage seed damage was determined from the equation;

$$D_s = \frac{Qd}{Qp} \times 100 \tag{3.25}$$

Where Q_d = Quantity of damaged seed (kg)

Q_p = Quantity of planted seed per unit time (kg)

D_s= percentage seed damage (%)

3.5.3 Spacing evenness E_u (cm)

The spacing evenness was calculated from the expression outlined by (FAO, 1994)

$$E_u = \frac{E - SSD}{E} \tag{3.26}$$

Where E_u = Spacing evenness

E = Average seed spacing

SSD = Seed spacing Standard Deviation

3.5.4 Number of seed per hill evenness E_n

$$E_n = \frac{N-NSD}{N} \quad (3.27)$$

Where N = Average number of seed

NSD = Number of seed standard deviation

3.5.5 Field efficiency ε (%)

The field efficiency was calculated from the equation below;

$$\varepsilon = \frac{Te}{Tt} \times 100 \quad (3.28)$$

Where ε = Field efficiency (%)

T_e = Effective time (min)

T_t = Total time

3.5.6 Effective field capacity C_{eff} (ha/hr)

The Theoretical field capacity was determined from the equation

$$C_{eff} = \frac{SWe}{10} \quad (3.29)$$

Where S = planter forward speed

W = planter effective width

e = field efficiency

3.5.7 Germination count C_g (%)

The germination count was obtained from the expression given below

$$C_g = \frac{S_g}{S} \times 100 \quad (3.30)$$

Where S_g = Germinated seed

S = Total seed planted

3.5.8 Seed depth evenness E_d (cm)

The seed depth evenness was determined from the formula below

$$E_d = \frac{D - DSD}{D} \quad (3.31)$$

Where D = Average depth

DSD =Depth standard deviation

3.6 Experimental Design and Analysis

The experiment comprised of three levels of planting speed (S1= 0.6m/s, S2=0.8m/s, and S3=1m/s), three levels of seed quantity (W1=25%, W2=50%, W3=100%) and two levels of planting depth (D1=1.5cm and D2=2.5cm). The experiment was laid in a Randomized Complete Block Design (RCBD) with three replications (Slope of the Field). Data obtained from the experiment was subjected to analysis of variance ANOVA using Statistical Analysis System SAS software. However, in the case of significant effect, the mean differences were tested using Duncan Multiple Range Test. The layout of the experiment is presented in appendix C2.

3.7 Cost Evaluation of Material

The table 3.2 shows the cost evaluation of material used in the research as year 2017.

Table 3.2 Cost Evaluation of Material

S/N	Material	Quantity	Price/Quantity (#)	Total Amount (#)
1	2 × 2 Angle Iron	3 Length	3300	9900
2	2 Inch × 5 mm Flat Bar	1 Length	4000	4000
3	1.5 mm Sheet Metal	¼ Sheet	3500	3500
4	17 Bolt and Nut	24 Pieces	50	1200
5	13 Bolt and Nut	16 Pieces	30	480
6	Metering Plate	4 Pieces	800	3200
7	Electrode	1 Pack	2000	2000
8	U.C Bearing	8 Pieces	1100	8800
9	25 mm Solid Shaft	4 Feet	4000	4000
10	200 mm Diameter Hollow Pipe	250mm Length	3000	3000
11	Threaded Shaft	1 Feet	500	500
12	Filling Disc	1 Pieces	700	1400
13	Cutting Disc	2 Pieces	800	1600
‘14	½ Inch Pipe	2 Pieces	2000	2000
15	3 Inch Pipe	2 Feet	1000	1000
16	¾ Inch Flat Bar	1 Length	500	1000
17	25 mm Rod	3 Feet	1000	1000
18	16 mm Rod	12 Feet	2000	2000
19	Spring and drill bit	8 Pieces	30	2000
20	Rubber Hose	2 Feet	400	1000
21	Transportation		2000	2000
22	Labour		15000	15000
	Total Amount			**# 70,580**

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 Diagram of the Four Row Planter

Plate 4.1 below shows the picture of the whole planter in four units having all the necessary components. The component parts include; the hopper, traction wheel, metering system, delivery tube, handle, pressing wheel, gauge wheel, furrow opener, animal hitch point and connecting bar.

Plate 4.1. Planter diagram on the field

4.2 Working Principle of the Planter

The machine consists of a circular vertical metering plate placed in a casing at the Centre of the frame, and on top the casing is the hopper in which seeds are poured. The circumference of the plate is drilled at center with six equally spaced cells near and flushing with the circumference of the metering plate, each then cell picks up single seeds at a time from the hopper via the bored hole on the casing. In front of the metering plate is an attachment of the Furrow opening device which opens the Furrow for the seeds to be placed inside, and this is due to the rotation of metering plate powered by the traction wheel on the ground. As the plate rotates below the hopper, the seed is picked up by the cells of the plate and carried on, until it is drop into the seed discharge tube and finally fall into the opened Furrow. The covering device that is attached behind the furrow opener covers the open furrow, and the press wheel compact the soil after the seed deposition on the seed, the process then continues to get uniform establishment of crop.

4.3 Laboratory Evaluation

This section presents the results and discussions of the laboratory evaluation of the planter.

4.3.1 Seed spacing evennes (E_u)

The result in table 4.1 below shows the effect of planting speed and seed hopper quantity on the seed spacing evenness. The highest spacing evenness was obtained at 25 and 50 % seed hopper quantity with 1 m/s planting speed, 25 % seed hopper quantity with 0.8 m/s planting speed and 50 % seed hopper quantity with 0.6 m/s planting speed. This may attribute to achieving better spacing evenness in seed spacing with decreasing seed hopper quantity with corresponding increase in speed. Also, the best seed spacing evenness was achieved at 0.6 m/s planting speed with 50 % seed hopper quantity. This result conforms with (Chinnan et al., 1975)

Table 4.1. Effect of Forward Speed and Seed Hopper Quantity on Seed Spacing

	1 m/s			0.8 m/s			0.6 m/s		
	1/4,	1/2,	1/1,	1/4,	1/2,	1/1,	1/4,	1/2,	1/1,
	28	26	24	25	26	25	23	24	25
	30	33	33	25	25	28	21	22	26
	29	29	27	25	26	25	24	24	25
	30	25	28	26	25	25	24	25	26
	24	25	26	24	26	25	21	25	25
	26	24	23	24	25	24	22	21	25
	27	35	26	26	24	25	22	24	25
	26	22	34	24	25	26	21	23	23
	25	22	39	26	25	22	21	24	28
	23	32	33	26	25	24	25	24	24
	27	28	31	25	26	25	24	25	25
	21	20	25	24	26	27	23	24	25
	26	28	28	26	28	25	23	25	26
	26	26	24	26	25	24	22	25	25
	28	27	24	25	22	26	23	25	25
	27	19	13	24	25	25	26	24	27
	13	21	13	25	25	26	25	25	25
	0	0	0	21	22	25	23	24	24
	0	0	0	24	21	13	19	22	13
	0	0	0	0	0	0	0	17	0
AVR	22	22	22	23	23	23	21	23	23
SSD	10.09	10.31	11.43	5.65	5.76	6.16	5.31	1.79	6.19
Eu	0.53	0.53	0.49	0.76	0.75	0.73	0.75	0.92	0.73

4.3.2 Seed drop per hill evenness

The result below shows the effect of planting speed and seed hopper quantity on the seed drop per hill evenness. The highest hill evenness was obtained at 50 % seed hopper quantity with 1 m/s planting speed, 25 % seed hopper quantity with 0.8 m/s planting speed as well as 50 and 100 % seed hopper quantity with 0.6 m/s planting speed. This may attribute to achieving better evenness in seed spacing with decreasing seed hopper quantity with corresponding increase in speed but the reverse was the case for 0.6 m/s planting speed. Also, the best seed spacing evenness is achieved at 0.8 m/s planting speed with 25 % seed hopper quantity.

Table 4.2. Effect of Forward Speed and Seed Hopper Quantity on Seed Drop per Hill

	1 m/s			0.8 m/s			0.6 m/s		
	1/4,	1/2,	1/1,	1/4,	1/2,	1/1,	1/4,	1/2,	1/1,
	2	2	2	1	1	1	1	1	1
	1	2	1	1	1	1	1	1	1
	2	1	1	1	1	2	1	1	2
	2	1	2	2	1	1	1	2	1
	1	2	2	1	1	1	2	1	1
	2	1	2	1	2	1	1	1	1
	2	1	1	1	1	1	1	1	1
	1	2	1	1	1	2	1	1	1
	1	1	2	1	2	1	1	2	2
	1	1	1	1	1	1	2	1	1
	2	2	1	2	1	1	1	1	1
	1	1	1	1	1	2	1	1	1
	1	1	2	1	1	1	1	1	1
	1	2	2	1	1	1	2	1	2
	2	2	1	1	1	1	1	1	1
	2	1	0	1	1	1	1	1	2
	0	0	0	1	1	2	1	2	1
	0	0	0	1	1	1	1	1	1
	0	0	0	1	1	0	1	2	1
	0	0	0	0	0	0	0	1	0
AVR	1	1	1	1	1	1	1	1	1
SSD	0.64	0.7	0.6	0.33	0.3	0.4	0.45	0.4	0.4
En	0.48	0.5	0.4	0.75	0.7	0.7	0.59	0.7	0.7

4.4 Field Evaluation

This section presents the results and discussion of the field performance evaluation of the planter.

4.4.1 Seed spacing

The results of the analysis of variance of the effect of planting speed, seed quantity and planting depth on seed spacing is presented in Table 4.3.

The result showed that the effect of planting speed was highly significant on seed spacing while seed quantity and planting depth is not significant. This indicates that the higher the forward speed the irregular the seed spacing and with lower speed the closer the spacing to recommended seed space as shown in Plate 4.8 below. This might attribute to the ability of the planter seed plate pick and meter seed at required/recommended spacing with medium or lower speed.

The first level of interaction for planting speed/seed quantity, planting speed/planting depth, seed quantity/planting depth and the second level of interaction for planting speed/seed quantity/planting depth are all highly significant on seed spacing.

Table 4.3: Effect of Planting Speed, Seed Quantity and Planting Depth on Seed Spacing (RCBD Anova)

Source	DF	SS	MS	F-value	Pr > F
Rep	2	2.65591481	1.32795741	4.87	0.0139
Planting speed (PS)	2	27.39995926	13.69997963	50.19**	<.0001
Seed quantity (SQ)	2	0.20540370	0.10270185	0.38NS	0.6892
Planting depth (PD)	1	0.00000741	0.00000741	0.00NS	0.9959
PS*SQ	4	7.50897407	1.87724352	6.88**	0.0004
PS*PD	2	10.53438148	5.26719074	19.30**	<.0001

SQ*PD	2	17.31304815	8.65652407	31.72**	<.0001
PS*SQ*PD	4	6.93752963	1.73438241	6.35**	0.0006
Error	34	9.27981852	0.27293584		
Total	53	81.83503704			

NS= Not significant**= Significant at (P≤0.01)

Mean separation using Duncan Multiple Range Test (DMRT) was further used to assess the effect of planting speed, seed quantity and planting depth on seed spacing and this was presented on table 4.4 below. The mean seed spacing among planting speed 0.6, 0.8 and 1m/s were significantly different but the same among the seed quantity of 25, 50 and 100 % full as well as between planting depth of 1.5 and 2.5 cm. The highest seed spacing of 23.5 cm was obtained at 0.8 m/s and least spacing of 22.82 cm at 0.6 m/s which could be attributed to the accurate or nearly accurate seed spacing with moderate forward speed and seed grading as shown in plate 4.3 below and irregular spacing with higher forward speed thereby agreeing with Isiaka (2000) and Wondwosen (2021) having a better planter performance at moderate seed spacing of 0.8 m/s

Table 4.4: Effect of Planting Speed, Seed Quantity and Planting Depth Influence on Seed Spacing

	Mean Seed spacing (cm)		
Treatment	**Seed spacing**	**IAR spacing**	**Recommended**
Planting speed (PS) (m/s)			
0.6	22.82b	25 cm	
0.8	23.50a		
1.0	21.77c		
SE±	0.123		
Seed quantity (SQ) (%)			
25	22.64		
50	22.78		
100	22.66		

SE±	0.123
Planting depth (PD) (cm)	
1.5	22.69
2.5	22.69
SE±	0.101
Interaction	
PS*SQ	**
PS*PD	**
SQ*PD	**
PS*SQ*PD	**

Means followed by same letter(s) in the same column are not different significantly at *P=0.05* using DMRT. **= Significant at ($P \leq 0.01$)

The DMRT for the first level of interaction among planting speed, seed quantity and planting depth on seed spacing are presented on Tables 4.5, 4.6, 4.7, and 4.8, respectively. Generally, from Table 4.5, the interactive effect of planting speed and seed quantity shows that 25% and 50% hopper seed quantity at 0.8 m/s recorded the highest mean seed spacing and were the same with 100% seed quantity at 0.6 m/s, but significantly different with other values at 0.6 and 1 m/s. Highest mean seed spacing of 23.63 cm for 50% seed quantity at 0.8 m/s and least mean seed spacing of 21.18 cm for 100% seed quantity at 1 m/s were recorded. This signifies that, with lower seed hopper quantity and speed, the better the seed spacing. Also, a better seed spacing may be obtained from the planter when the hopper quantity was increased to the peak of 100 % with the least forward speed of 0.6 m/s, this may be attributed to the stable planting operation, lower field capacity but the case of refilling the hopper was taken care of. This agrees with Nwachukwu *et al* (2000) who obtained similar report

Table 4.5: Effect of Interaction Between Planting Speed and Seed Quantity on Seed Spacing.

Mean Seed spacing (cm)			
Treatment	**Planting speed (m/s)**		
Seed quantity (%)	0.6	0.8	1.0
25	22.26cd	23.53a	22.14cd
50	22.74bc	23.63a	21.97d
100	23.45a	23.34ab	21.18e
SE±	0.213		

Means followed by same letter(s) in the same column and row are not different significantly at *P=0.05* using DMRT.

Table 4.6 below shows the interactive effect of planting speed and planting depth on the seed spacing. Generally, the 1.5 cm planting depth at 0.8 m/s and 2.5 cm planting depth at both planting speed of 0.6 m/s and 0.8 m/s recorded the highest mean seed spacing and are significantly the same, but significantly different at 0.6 m/s and 1 m/s. Highest mean seed spacing of 23.52 cm for 1.5 cm planting depth at 0.8 m/s and least mean seed spacing of 21.24 cm for 2.5 cm planting depth at 1 m/s were recorded. This shows that the machine could operate with a better seed spacing at a moderate forward speed regardless of whether the penetration of the furrow opener in the soil was increased or decreased. This agrees with Mandal *et al* (2013) who obtained the highest field result with 0.8 m/s.

Table 4.6: Effect of Interaction Between Planting Speed and Planting Depth on Seed Spacing

Mean Seed spacing (cm)			
Treatment	**Planting speed (m/s)**		
Planting depth (cm)	0.6	0.8	1.0
1.5	22.26b	23.52a	22.29b
2.5	23.37a	23.47a	21.24c
SE±		0.174	

Means followed by same letter(s) in the same column and row are not different significantly at *P=0.05* using DMRT.

Table 4.7 below shows the effect of seed quantity and planting depth interaction on the seed spacing. The 1.5 cm planting depth at 100% and 2.5 cm at 25% seed quantity recorded the highest mean seed spacing and were the same, but significantly different at 50% seed quantity. This may be attributed to the more weight on the planter due to maximum loading on the planter with shallow furrow opener penetration, or minimum loading on the planter with deep recommended furrow opener penetration, thereby reducing the machine mechanical vibration. A better seed spacing with effective emergence was obtained on the field as the combination of these factors help to stabilize the planting operation for effective seed metering. Highest mean seed spacing of 23.41 cm for 2.5 cm planting depth at 25% and least mean seed spacing of 21.88 cm for 1.5 cm planting depth at 25% were recorded. This agrees with Oduma *et al* (2014) who obtained best spacing at 2.22 cm planting depth and this very closed to the recommended depth of 2.5 cm by Anderson (2002)

Table 4.7: Effect of Interaction Between Seed Quantity and Planting Depth on Seed Spacing

Mean Seed spacing (cm)			
Treatment	**Seed quantity (%)**		
	25	50	100
Planting depth (cm)			
1.5	21.88c	22.95ab	23.25a
2.5	23.41a	22.61b	22.06c
SE+		0.174	

Means followed by same letter(s) in the same column and row are not different significantly at *P=0.05* using DMRT.

The DMRT on the second level of interaction effect among planting speed, seed quantity and planting depth on seed spacing was presented on Table 4.8. At 0.8 m/s planting speed with seed quantity of 25% and planting depth of 2.5 cm, the highest seed spacing of 23.92 cm which was the same as 23.87 cm seed spacing at 0.8 m/s with 50% and 1.5 cm was recorded. The least seed spacing of 19.37 cm at 1 m/s, 100% and 2.5 cm was recorded. This indicate that the best seed spacing could be obtained at medium planter forward speed and seed quantity with a shallow soil penetration as lower weight of soil is opened. This conform with panning et al (2000).

Table 4.8: Effect of Interaction Between Planting Speed, Seed Quantity and Planting Depth on Seed Spacing.

Mean Seed spacing (cm)			
Planting speed(m/s)	Seed quantity (%)	Planting depth (cm)	Seed spacing (cm)
	25	1.5	21.02g
		2.5	23.50a-d
0.6	50	1.5	22.59de
		2.5	22.89b-e
	100	1.5	23.18a-e

		2.5	23.72abc
	25	1.5	23.13a-e
		2.5	23.92a
0.8	50	1.5	23.87ab
		2.5	23.39a-e
	100	1.5	23.57a-d
		2.5	23.11a-e
	25	1.5	21.49fg
		2.5	22.80cde
1.0	50	1.5	22.40ef
		2.5	21.55fg
	100	1.5	23.00a-e
		2.5	19.37h
SE±			0.302

Means followed by same letter(s) in the same column are not different significantly at *P=0.05* using DMRT.

4.4.2 Germination counts

The results of the analysis of variance of the effect of planting speed, seed quantity and planting depth on germination count was presented in Table 4.9 below.

The result shows that the effect of planting speed, seed quantity and planting depth were all highly significant on germination count. The first level of interaction for planting speed/seed quantity, planting speed/planting depth were also highly significant, but significant for seed quantity/planting depth and the second level of interaction for planting speed/seed quantity/planting depth on germination count.

Table 4.9: Effect of Planting Speed, Seed Quantity and Planting Depth on Germination Count (RCBD Anova)

Source	DF	SS	MS	F-value	Pr > F
Rep	2	9.592593	4.796296	0.99	0.3814
Planting speed (PS)	2	1589.370370	794.685185	164.34**	<.0001
Seed quantity (SQ)	2	67.703704	33.851852	7.00**	0.0028
Planting depth (PD)	1	249.185185	249.185185	51.53**	<.0001
PS*SQ	4	300.629630	75.157407	15.54**	<.0001
PS*PD	2	349.592593	174.796296	36.15**	<.0001
SQ*PD	2	36.592593	18.296296	3.78*	0.0328
PS*SQ*PD	4	69.296296	17.324074	3.58*	0.0153
Error	34	164.407407	4.835512		
Total	53	2836.370370			

*= Significant at (P= $\leq$ 0.05) **= Significant at (P$\leq$0.01)

Mean separation using Duncan Multiple Range Test (DMRT) was further used to assess the effect of planting speed, seed quantity and planting depth on seed germination count and was presented on table 4.10 below. The mean seed germination counts between speed 0.6, 0.8 and 1 m/s were significantly different but the same between the seed quantity of 25 and 50% and different at 100 % seed quantity as well as between planting depth of 1.5 and 2.5 cm. The highest germination counts of 88.5, 82.8 and 83.4 was obtained at 0.6 m/s planting speed, 100% seed quantity and 1.5 cm planting depth and least germination count of 74.8, 80.1 and 79.1 at 1 m/s, 50% and 2.5 cm respectively. This may be attributed to good plant population at a low speed, high hopper seed quantity and shallow furrow opening of the soil, it conforms the result obtained by Nielsen (2013) who obtained a high plant establishment under a low planting speed

Table 4.10: Effect of Planting Speed, Seed Quantity and Planting Depth Influence on Germination Count and Seed Rate

	Mean Germination count (%)	
Treatment	**Germination count**	**IAR Recommended**
Planting speed (PS) (m/s)		
0.6	88.5a	100 % (53333 seeds/ha)
0.8	80.9b	
1.0	74.8c	
SE±	0.518	
Seed quantity (SQ) (%)		
25	80.9b	
50	80.1b	
100	82.8a	
SE±	0.518	
Planting depth (PD) (cm)		
1.5	83.4a	
2.5	79.1b	
SE±	0.423	
Interaction		
PS*SQ	**	
PS*PD	**	
SQ*PD	**	
PS*SQ*PD	**	

**= Significant at ($P \leq 0.01$) Means followed by same letter(s) in the same column are not different significantly at $P=0.05$ using DMRT

The DMRT for the first level of interaction between planting speed, seed quantity and planting depth on seed germination count and seed rate are presented on Tables 4.11, 4.12, 4.13, 4.14, 4.15 and 4.16, respectively. Table 4.10 shows the effect of planting speed/seed quantity interaction on the germination count. The 100% hopper seed quantity at 0.6 m/s recorded the highest mean seed germination count and is significantly different from 25 and 50% which are significantly the same at same speed, the 25, 50 and 100% seed quantity were the same at 0.8 m/s but significantly different at 1 m/s. Highest mean germination count of 94.0 percent for 100% seed quantity at 0.6 m/s and least mean germination count of 73 for 100% seed quantity at 1 m/s were recorded. This attribute to consistent seed metering and discharge due to lowest forward speed with maximum loading of seed on the machine. This also shows that, the lower the planting speed with maximum seed hopper quantity, the better and stable the planter discharges seed resulting in good germination. This agrees with Nwachukwu *et al* (2000), Adisa and Braide (2012).

Table 4.11: Effect of Interaction Between Planting Speed and Seed Quantity on Germination Count

	Mean Germination count (%)		
Treatment	**Planting speed (m/s)**		
	0.6	0.8	1.0
Seed quantity (%)			
25	84.7b	81.2c	76.8d
50	85.5b	80.3c	74.5de
100	94.0a	81.3c	73.0e
SE±		0.898	

Means followed by same letter(s) in the same column and row are not different significantly at *P=0.05* using DMRT.

Table 4.12 below shows the effect of planting speed/planting depth interaction on the seed germination count. The 1.5 cm planting depth at 0.6 m/s recorded the highest mean seed germination count and is significantly different at 0.8 and 1 m/s, but the same for 1.5 and 2.5 cm at both 0.8 and 1 m/s. The highest mean seed germination counts of 93.8 % for 1.5 cm planting depth at 0.6 m/s and least mean seed germination count of 74.8 for 1.5 and 2.5 cm planting depth at 1 m/s were recorded. The low planting speed with decrease in planting depth also attribute to good metering and discharge of seed into the soil, and this also result to effective emergence of seedlings. This is similar to the result obtained by Tarig et al (2013) who realized a greater plant population with shallow planting depth and low speed.

Table 4.12: Effect of Interaction Between Planting Speed and Planting Depth on Germination Count

Mean Germination count (%)			
Treatment	**Planting speed (m/s)**		
	0.6	0.8	1.0
Planting depth (cm)			
1.5	93.8a	81.7b	74.8c
2.5	82.3b	80.2b	74.8c
SE±		0.733	

Means followed by same letter(s) in the same column and row are not different significantly at *P=0.05* using DMRT.

Table 4.13 below shows the effect of seed quantity/planting depth interaction on the seed germination count. The 1.5 cm planting depth at 100%seed quantity recorded the highest mean seed germination count and is significantly different, but were the same at 25 and 50% seed quantity. The 2.5 cm planting depth is also significantly the same at 25, 50 and 100 % seed quantity. Highest mean germination counts of 86 for 1.5 cm planting depth at 100 % and least mean germination count of 78.1for 1.5 cm planting depth at 50 % were recorded. This may attribute to effective plant emergence with shallow planting depth and free flow of seed in the hopper as a result high pressure of seed leading to good metering and the planter down weight. This conforms with Virk et al (2019) having a nice plant population with shallow planting depth and high down weight of the planter.

Table 4.13: Effect of Interaction Between Seed Quantity and Planting Depth on Germination Count

Mean Germination count (%)			
Treatment	**Seed quantity (%)**		
	25	50	100
Planting depth (cm)			
1.5	82.1b	82.1b	86.0a
2.5	79.7c	78.1c	79.6c
SE±		0.733	

Means followed by same letter(s) in the same column and row are not different significantly at *P=0.05* using DMRT.

The DMRT on the second level of interaction between planting speed, seed quantity and planting depth on germination count was presented on Table 4.14. At 0.6 m/s planting speed with seed quantity of 100% and planting depth of 1.5 cm, the highest germination counts of 100% which was significantly different from others was recorded. The least germination counts of 73.0% at 1 m/s speed, 100% seed quantity, 1.5 and 2.5 cm planting depth was recorded. This may be attributed to the good plant population at a low speed, high hopper seed quantity and shallow furrow opening of the soil. This may also be as a result of consistent seed metering due to low speed, stable operation due to the increase in hopper weight and shallow opening of soil. Nwachukwu *et al* (2000) constructed a single row planter and obtained the highest germination count of 58 % at 0.6 m/s forward speed.

Table 4.14: Effect of Interaction Between Planting Speed, Seed Quantity and Planting Depth on Seed Germination Count.

Mean Germination count (%)			
Planting speed (m/s)	Seed quantity (%)	Planting depth (cm)	Germination count (%)
0.6	25	1.5	87.7c
		2.5	81.7ef
	50	1.5	92.0b
		2.5	79.0fg
	100	1.5	100.0a
		2.5	86.3cd
0.8	25	1.5	80.7ef
		2.5	81.7ef
	50	1.5	81.0ef
		2.5	79.7efg
	100	1.5	83.3de
		2.5	79.3efg
1.0	25	1.5	78.0fg
		2.5	75.7gh
	50	1.5	73.3h
		2.5	75.7gh
	100	1.5	73.0h
		2.5	73.0h
SE±			1.270

Means followed by same letter(s) in the same column are not different significantly at *P=0.05*using DMRT.

4.4.3 Seed rate

The results of the analysis of variance of the effect of planting speed, seed quantity and planting depth on seed rate is presented in Table 4.15 below.

The result shows that the effect of planting speed, seed quantity and planting depth are highly significant on seed rate. The first level of interaction for planting speed/seed quantity, planting speed/planting depth, seed quantity/planting depth are all highly significant as well except for the second level of interaction for planting speed/seed quantity/planting depth which is not significant on seed rate.

Table 4.15: Effect of Planting Speed, Seed Quantity and Planting Depth on Seed Rate (RCBD Anova)

Source	DF	SS	MS	F-value	Pr > F
Rep	2	0.23732968	0.11866484	0.35	0.7079
Planting speed (PS)	2	91.16385917	45.58192958	134.04**	<.0001
Seed quantity (SQ)	2	3.52424326	1.76212163	5.18**	0.0109
Planting depth (PD)	1	14.51851852	14.51851852	42.69**	<.0001
PS*SQ	4	24.57166895	6.14291724	18.06**	<.0001
PS*PD	2	24.44466392	12.22233196	35.94**	<.0001
SQ*PD	2	4.23067215	2.11533608	6.22**	0.0050
PS*SQ*PD	4	3.10606310	0.77651578	2.28NS	0.0805
Error	34	11.5618473	0.3400543		
Total	53	177.3588660			

NS= Not significant**= Significant at ($P \leq 0.01$)

The mean separation using Duncan Multiple Range Test (DMRT) was used to further assess the effect of planting speed, seed quantity and planting depth on seed rate was presented on table 4.16 below. The mean seed rate between speed 0.6, 0.8 and 1 m/s were significantly different and significantly the same between the seed quantity of 25 and 50% but different at 100 % seed quantity as well as between planting depth of 1.5 and 2.5 cm. The highest seed rate of 20.7, 19.4 and 19.5 kg/ha were obtained at 0.6 m/s planting speed, 100% seed quantity and 1.5 cm planting depth and least seed rate of 17.5, 18.8 and 18.5 kg/hr respectively at 1 m/s, 50% and 2.5 cm respectively were recorded. This conform with the result obtained by Upahi (2017) having an average seed rate of 19.8 kg/ha with planting speed of 0.55 m/s. This may be as a result of planting with low speed leading to effective metering and discharge, the maximum weight on the hopper leading to the steady picking of the seed by the metering and the shallow planting depth leading effective emergence.

Table 4.16: Effect of Planting Speed, Seed Quantity and Planting Depth Influence on Germination Count and Seed Rate

	Seed rate($Kgha^{-1}$)	
Treatment	**Seed rate**	**IAR Recommended**
Planting speed (PS) (m/s)		
0.6	20.7a	20 kg/ha
0.8	18.9b	
1.0	17.5c	
SE±	0.137	
Seed quantity (SQ) (%)		
25	18.9b	
50	18.8b	
100	19.4a	
SE±	0.137	
Planting depth (PD) (cm)		
1.5	19.5a	

2.5	18.5b
SE±	0.112
Interaction	
PS*SQ	**
PS*PD	**
SQ*PD	**
PS*SQ*PD	NS

Means followed by same letter(s) in the same column are not different significantly at *P=0.05* using DMRT NS= Not Significant **= Significant at (P≤0.01)

Table 4.17 below shows the effect of planting speed/seed quantity interaction on seed rate. The 100% hopper seed quantity at 0.6 m/s recorded the highest mean seed rate and is significantly different from 25 and 50%, the 50 and 100% seed quantity are significantly the same at 0.8 m/s. Highest mean seed rater of 22.3 kg/ha for 100% seed quantity at 0.6 m/s and least mean seed rate of 17.0 kg/ha for 100% seed quantity at 1 m/s were recorded. This may attribute to low forward speed operation with high quantity of seed in the hopper leading to higher seed rate greater than the IAR recommended rate as a result of the planter dropping more than one seed in the rows of some of the treatment plot. This may cause competition of plant for nutrient. A better result can be obtained at 0.6 m/s planting speed with 50 and 25 % seed hopper quantity. This is similar to the result obtained by Nielson (1995)

Table 4.17: Effect of Interaction Between Planting Speed and Seed Quantity on Seed Rate.

Mean Seed rate (Kgha^{-1})			
Treatment	**Planting speed (m/s)**		
	0.6	0.8	1.0
Seed quantity (%)			
25	19.6bc	19.0cd	18.1ef
50	20.1b	18.8de	17.5fg
100	22.3a	18.8de	17.0g
SE±		0.238	

Means followed by same letter(s) in the same column and row are not different significantly at *P=0.05* using DMRT.

Table 4.18 below shows the effect of planting speed/planting depth interaction on the seed rate. The 1.5 cm planting depth at 0.6 m/s recorded the highest mean seed rate and is significantly different at 0.8 and 1 m/s, but were the same for 1.5 and 2.5 cm at 0.8 and 2.5 cm at 0.6 m/s. The highest mean seed rate of 19.2 kg/ha for 2.5 cm planting depth at 0.6 m/s and least mean seed rate of 17.5kg/ha for 2.5 cm planting depth at 1 m/s were recorded. This may attribute to the low forward speed and low planting depth leading to effective metering. The reason for the higher seed rate deviating from the recommended 20 kg/ha may be as a result of picking and dropping more than one seed along the row of some of the treatment plot as mentioned above. This is in accordance with the result obtained by Agidi et al (2017) who obtained a high seed rate with low planting speed and and planting depth.

Table 4.18: Effect of Interaction Between Planting Speed and Planting Depth on Seeding Rate.

	Mean Seed rate (Kgha^{-1})		
Treatment	**Planting speed (m/s)**		
	0.6	0.8	1.0
Planting depth (cm)			
1.5	22.2a	19.0b	17.5c
2.5	19.2b	18.7b	17.5c
SE±		0.194	

Means followed by same letter(s) in the same column and row are not different significantly at *P=0.05* using DMRT.

Table 4.19 below shows the effect of seed quantity/planting depth interaction on the seed rate. The 1.5 cm planting depth at 100% seed quantity recorded the highest mean seed rate and is significantly different, but significantly the same at 25 and 50% seed quantity. The 2.5 cm planting depth was also the same at 25, 50 and 100 % seed quantity. Highest mean seed rate of

20.3 kg/ha for 1.5 cm planting depth at 100 % and least mean seed rate of 18.3 kg/ha for 2.5 cm planting depth at 50 % were recorded. Here there is uniform consumption of plant nutrients. This may be due to high seed quantity in the hopper and low planting depth causing quick and effective emergence as seeds are not sowed deeply into the soil. This conforms with Virk et al (2019)

Table 4.19: Effect of Interaction Between Seed Quantity and Planting Depth on Seeding Rate.

Mean Seed rate ($Kgha^{-1}$)			
Treatment	**Seed quantity (%)**		
	25	50	100
Planting depth (cm)			
1.5	19.1b	19.2b	20.3a
2.5	18.7bc	18.3c	18.5c
SE$\pm$		0.194	

Means followed by same letter(s) in the same column and row are not different significantly at *P=0.05* using DMRT.

4.4.4 Field efficiency

The results of the analysis of variance of the effect of planting speed, seed quantity and planting depth on field efficiency is presented in Table 4.20 below.

The result shows that the effect of planting speed, seed quantity and planting depth are highly significant on field efficiency. The whole first level of interaction for planting speed/seed quantity, planting speed/planting depth, seed quantity/planting depth and the second level of interaction for planting speed/seed quantity/planting depth are all highly significant on field efficiency.

Table 4.20: Effect of Planting Speed, Seed Quantity and Planting Depth on Field Efficiency. (RCBD Anova)

Source	DF	SS	MS	F-value	Pr > F
Rep	2	62.215671	31.107835	5.57	0.0081
Planting speed (PS)	2	253.444565	126.722283	22.68**	<.0001
Seed quantity (SQ)	2	1314.089115	657.044557	117.58**	<.0001
Planting depth (PD)	1	357.224508	357.224508	63.93**	<.0001
PS*SQ	4	498.308687	124.577172	22.29**	<.0001
PS*PD	2	134.422259	67.211130	12.03**	0.0001
SQ*PD	2	291.852717	145.926359	26.11**	<.0001
PS*SQ*PD	4	443.144206	110.786052	19.83**	<.0001
Error	34	189.990124	5.587945		
Total	53	3544.691854			

**= Significant at ($P \leq 0.01$)

4.4.5 Field capacity

The results of the analysis of variance of the effect of planting speed, seed quantity and planting depth on field capacity presented in Table 4.21 below.

The result shows that the effect of planting speed, seed quantity and planting depth are highly significant on field capacity. The first level of interaction for planting speed/seed quantity and seed quantity/planting depth are highly significant, while planting speed/planting depth is only significant. The second level of interaction for planting speed/seed quantity/planting depth is highly significant on field capacity.

Table 4.21: Effect of Planting Speed, Seed Quantity and Planting Depth on Field Capacity. (RCBD Anova:)

Source	DF	SS	MS	F-value	Pr > F
Rep	2	0.00235926	0.00117963	5.44	0.0089
Planting speed (PS)	2	0.36285926	0.18142963	836.53**	<.0001
Seed quantity (SQ)	2	0.05428148	0.02714074	125.14**	<.0001

Planting depth (PD)	1	0.01185185	0.01185185	54.65**	<.0001
PS*SQ	4	0.02694074	0.00673519	31.05**	<.0001
PS*PD	2	0.00197037	0.00098519	4.54*	0.0178
SQ*PD	2	0.01317037	0.00658519	30.36**	<.0001
PS*SQ*PD	4	0.01800741	0.00450185	20.76**	<.0001
Error	34	0.00737407	0.00021688		
Total	53	0.49881481			

*= Significant at ($P \leq 0.05$) **= Significant at ($P \leq 0.01$)

The mean separation using Duncan Multiple Range Test (DMRT) was further used to assess the effect of planting speed, seed quantity and planting depth on field efficiency and field capacity were presented on Table 4.22 below. The mean field efficiency between speed 0.6 and 0.8m/s were the same and significantly different between the seed quantity of 25, 50 and 100 % full as well as between planting depth of 1.5 and 2.5 cm. The highest field efficiency of 72.2, 75.3 and 72.6 % at 0.8 m/s planting speed, 50 % seed quantity and 2.5 cm planting depth and least efficiency of 67.1, 63.5 and 67.5 % at 1 m/s, 100 % and 1.5 cm were obtained respectively. This agrees with the result obtained by Oduma *et al* (2014) having field efficiency of 71.71 % with planting depth of 2.22 cm.

The mean field capacity between same speed, seed quantity and planting depth were significantly different. The higher mean field capacity of 0.54, 0.48 and 0.47 ha/hr at 1 m/s, 50 % and 2.5 cm were recorded and the least of 0.34, 0.41 and 0.44 ha/hr at 0.6 m/s, 100 % and 1.5 cm were obtained respectively. This conform with the field capacity obtained by Oduma *et al* (2014) and Upahi (2017) having 0.26 ha/hr with planting depth of 2.22 cm and 0.22 ha/hr and planting speed of 0.55 m/s respectively. The high mean field capacity was as a result of larger width of operation (i.e. four row).

Table 4.22: Effect of Planting Speed, Seed Quantity and Planting Depth on Field Efficiency and Field Capacity.

Mean Field efficiency (%) and Field capacity(ha/hr)		
Treatment	**Field efficiency**	**Field capacity**
Planting speed (PS) (m/s)		
0.6	70.9a	0.34c
0.8	72.2a	0.47b
1.0	67.1b	0.54a
SE$\pm$	0.557	0.004
Seed quantity (SQ) (%)		
25	71.3b	0.46b
50	75.3a	0.48a
100	63.5c	0.41c
SE$\pm$	0.557	0.004
Planting depth (PD) (cm)		
1.5	67.5b	0.44b
2.5	72.6a	0.47a
SE$\pm$	0.455	0.003
Interaction		
PS*SQ	**	**
PS*PD	**	*
SQ*PD	**	**
PS*SQ*PD	**	**

*= Significant at ($P \leq 0.05$) **= Significant at ($P \leq 0.01$). Means followed by same letter(s) in the same column are not different significantly at *P=0.05* using DMRT.

The DMRT for the first level of interaction between planting speed, seed quantity and planting depth on field efficiency and field capacity are presented on Tables 4.23, 4.24, 4.25, 4.26, 4.27 and 4.28 respectively. The Table 4.20 shows the effect of planting speed/seed quantity interaction on the field efficiency. Generally, the 50% hopper seed quantity at 0.8 m/s recorded the highest mean field efficiency and is significantly different, the 25 % at 0.6 and 1 m/s, 25, 50 and 100 % at 0.8 and 1 m/s as well as 50 % seed quantity at 1 m/s are significantly the same respectively. Highest mean field efficiency of 80.8 % for 50% seed quantity at 0.8 m/s and least mean field efficiency of 59.1 % for 100% seed quantity at 1 m/s were recorded. The high mean field efficiency may attribute to the intermediate seed hopper quantity and forward speed used as the operation was done at a reasonable seed hopper quantity and primary functional time. This agrees with Isiaka *et al*. (2000) having highest field efficiency of 85 % with forward speed of 0.82 m/s.

Table 4.23: Effect of Interaction Between Planting Speed and Seed Quantity on Field Efficiency.

	Mean Field efficiency (%)		
Treatment		**Planting speed (m/s)**	
	0.6	0.8	1.0
Seed quantity (%)			
25	73.0c	67.9d	73.0c
50	76.1b	80.8a	69.1d
100	63.4e	67.9d	59.1f
SE±		0.965	

Means followed by same letter(s) in the same column and row are not different significantly at *P=0.05* using DMRT.

Table 4.24 below expresses the effect of planting speed/planting depth interaction on the field efficiency. The 2.5 cm planting depth at 0.6 and 0.8 m/s recorded the highest mean field efficiency and are significantly different, but the same for 1.5 at 0.6 and 1 m/s as well as 1.5 and 2.5 cm at 0.8 and 1 m/s. The highest mean field efficiency of 75.7 % for 2.5 cm planting depth at 0.6 m/s and least mean efficiency of 65.7 % for 1.5 cm planting depth at 1 m/s were recorded. The good result obtained was as a result of high planting depth and low forward speeds. This agrees with Gambari *et al* (2017) having an increasing efficiency with a decreasing planting speed.

Table 4.24: Effect of Interaction Between Planting Speed and Planting Depth on Field Efficiency.

Mean Field efficiency (%)			
Treatment	**Planting speed (m/s)**		
	0.6	0.8	1.0
Planting depth (cm)			
1.5	66.1c	70.6b	65.7c
2.5	75.7a	73.7a	68.4b
SE±		0.788	

Means followed by same letter(s) in the same column and row are not different significantly at *P=0.05* using DMRT.

Table 4.25 below shows the effect of seed quantity/planting depth interaction on the field efficiency. The 2.5 cm planting depth at 50% seed quantity recorded the highest mean seed rate and is significantly different, but were the same for 1.5 cm at 25 and 50% seed quantity, as well as 2.5 cm planting depth at 25 %. Highest mean field efficiency of 78.8 % for 2.5 cm planting depth at 50 % and least mean field efficiency of 58.6 % for 1.5 cm planting depth at 100 % were recorded. The results show that planting at intermediate seed hopper quantity and high planting depth yield a better result of field efficiency. This conforms with Virk et al (2014)

Table 4.25: Effect of Interaction Between Seed Quantity and Planting Depth on Field Efficiency.

Mean Field efficiency (%)			
Treatment	**Seed quantity (%)**		
	25	50	100
Planting depth (cm)			
1.5	71.9b	71.9b	58.6d
2.5	70.7b	78.8a	68.3c
SE±		0.788	

Means followed by same letter(s) in the same column and row are not different significantly at *P=0.05* using DMRT.

Table 4.26 below shows the effect of planting speed/seed quantity interaction on the field capacity. Generally, the 25% hopper seed quantity at 1 m/s recorded the highest mean field capacity and is significantly different, the 25and 50 % at 0.6 m/s, as well as 25 and 100 % at 0.8 m/s are the same respectively. Highest mean field capacity of 0.59 ha/hr for 25% seed quantity at 1 m/s and least mean field capacity of 0.31 ha/hr for 100% seed quantity at 0.6 m/s were recorded. The higher the planting speed with lower seed quantity the higher the field capacity as forward speed is one of the major determinant of field capacity. This may be attributed to the planter properly picking and discharging seed with low seed quantity if moving fast, but this will attract refilling the hopper twice after the first filling. This conforms with Colburn (2017)

Table 4.26: Effect of Interaction Between Planting Speed and Seed Quantity on Field Capacity.

Mean Field capacity (ha/hr)			
Treatment	**Planting speed (m/s)**		
	0.6	0.8	1.0
Seed quantity (%)			
25	0.36f	0.44e	0.59a
50	0.37f	0.52c	0.56b
100	0.31g	0.44e	0.48d
SE±		0.006	

Means followed by same letter(s) in the same column and row are not different significantly at *P=0.05* using DMRT.

Table 4.27 below shows the effect of planting speed/planting depth interaction on the seed spacing. The 2.5 cm planting depth at 1 m/s recorded the highest mean field capacity and is significantly different. The highest mean field capacity of 0.55 ha/hr for 2.5 cm planting depth at

1 m/s and least mean field capacity of 0.32 ha/hr for 1.5 cm planting depth at 0.6 m/s were recorded.

Table 4.27: Effect of Interaction Between Planting Speed and Planting Depth on Field Capacity.

Mean Field capacity (ha/hr)			
Treatment	**Planting speed (m/s)**		
	0.6	0.8	1.0
Planting depth (cm)			
1.5	0.32f	0.46d	0.53b
2.5	0.37e	0.48c	0.55a
SE±		0.005	

Means followed by same letter(s) in the same column and row are not different significantly at *P=0.05* using DMRT.

Table 4.28 below shows the effect of seed quantity/planting depth interaction on the field capacity. The 2.5 cm planting depth at 50% seed quantity recorded the highest mean field capacity and is significantly different, but the same for 1.5 cm at 25 and 50% seed quantity. The 2.5 cm planting depth is also significantly the same at 25 % seed quantity. Highest mean field capacity of 0.51 ha/hr for 2.5 cm planting depth at 50 % and least mean seed rate of 0.38 ha/hr for 1.5 cm planting depth at 100 % were recorded. This shows that the field capacity is best determined at high planting depth and intermediate seed hopper quantity used. This corresponds with the findings made by Poncet et al (2018)

Table 4.28: Effect of Interaction Between Seed Quantity and Planting Depth on Field Capacity.

Mean Field capacity (ha/hr)			
Treatment	**Seed quantity (%)**		
	25	50	100
Planting depth (cm)			

1.5	0.47b	0.46b	0.38d
2.5	0.46b	0.51a	0.44c
SE±		0.005	

Means followed by same letter(s) in the same column and row are not different significantly at *P=0.05* using DMRT.

The DMRT on the second level of interaction between planting speed, seed quantity and planting depth on field efficiency and field capacity was presented on table 4.29. At 0.8 m/s planting speed with seed quantity of 50% and planting depth of 2.5 cm, the highest field efficiency of 86.9 % which was significantly different from others was recorded. The 0.8 m/s, 25 %, 1.5 cm and 0.8 m/s, 50 %, 1.5 cm are the same, as well as 0.8 m/s, 100 %, 2.5 cm and 1 m/s, 25 %, 1.5 and 2.5 cm are also the same. The best result obtained was as a result of intermediate forward speed and seed hopper quantity used and high planting depth. This agrees with Isiaka *et al.* (2000) and the high mean field efficiency obtained was as a result of more number of rows (i.e. 4 rows). Likewise, at same planting speed, seed quantity and planting depth of 1 m/s, 25%, 1.5 cm, the highest field capacity of 0.59 ha/hr which was the same at 1 m/s with 25 % and 2.5 cm was recorded. The 1 m/s, 50 %, 1.5 cm and 0.8 m/s, 50 %, 2.5 cm are significantly the same, 1 m/s, 100 %, 2.5 cm / 0.8 m/s, 100 %, 2.5 cm / 0.8 m/s, 50 %, 1.5 cm and 0.8 m/s, 25 %, 1.5 cm are significantly the same as well as 0.6 m/s, 100 %, 2.5 cm / 0.6 m/s, 50 %, 1.5 cm and 0.6 m/s, 25 %, 1.5 cm. The least field efficiency of 56 % for 1 m/s, 100% and 1.5 cm and field capacity of 0.28 ha/hr for 0.6 m/s, 100 % and 1.5 cm was recorded. The result shows that, with either increased or decreased planting depth, the best field capacity is obtained at high forward speed and low seed hopper quantity.

Table 4.29: Effect of Interaction Between Planting Speed, Seed Quantity and Planting Depth on Field Efficiency and Field Capacity.

Mean Field efficiency (%) and Field capacity (ha/hr)				
Planting speed(m/s)	Seed quantity (%)	Planting depth (cm)	Field efficiency (%)	Field capacity (ha/hr)
0.6	25	1.5	67.9f	0.33f
		2.5	78.2bc	0.38e
	50	1.5	72.7de	0.35f
		2.5	79.6b	0.39e
	100	1.5	57.6hi	0.28g
		2.5	69.3ef	0.34f
0.8	25	1.5	75.1cd	0.49c
		2.5	60.7gh	0.39e
	50	1.5	74.6cd	0.48c
		2.5	86.9a	0.56b
	100	1.5	62.2g	0.40e
		2.5	73.6de	0.48c
1.0	25	1.5	72.8de	0.59a
		2.5	73.3de	0.59a
	50	1.5	68.3f	0.55b
		2.5	70.0ef	0.57ab
	100	1.5	56.0i	0.45d
		2.5	62.1g	0.50c
SE±			1.365	0.009

Means followed by same letter(s) in the same column are not different significantly at *P=0.05* using DMRT.

4.4.6 Seed drop per hill

The Analysis of Variance ANOVA for seed drop per hill is presented on Table 4.30 below. The result shows that the effect of planting speed, seed quantity and planting depth are not significant on seed drop per hill. The first level of interaction for planting speed/seed quantity, planting speed/planting depth, seed quantity/planting depth and the second level of interaction for planting speed/seed quantity/planting depth are also not significant on seed drop per hill as the average seed drop in all treatment is ONE (1) and the result obtained yield no any interaction as shown in plate 4.8.

Table 4.30: Effect of Planting Speed, Seed Quantity and Planting Depth on Seed Drop Per Hill.

Source	DF	SS	MS	F-value	Pr > F
Rep	2	0	0	-	-
Planting speed (PS)	2	0	0	-	-
Seed quantity (SQ)	2	0	0	-	-
Planting depth (PD)	1	0	0	-	-
PS*SQ	4	0	0	-	-
PS*PD	2	0	0	-	-
SQ*PD	2	0	0	-	-
PS*SQ*PD	4	0	0	-	-
Error	34	0	0		
Total	53	0			

NS= Not significant**= Significant at ($P\leq0.01$)

Plate 4.2. Planting Process

Plate 4.3. Seed Grading

Plate 4.4. Seed Weighing

Plate 4.5. Average Draft Measurement

Plate 4.6. Beginning of the planting process

Plate 4.7. Dynamometer attachment

Plate 4.8. Plant spacing measurement

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary

The research work titled development and performance evaluation of a four rows animal drawn precision seed planter was carried out at the Department of Agricultural and Bio-resources Engineering, Ahmadu Bello University, Zaria. The research entails Design analysis, construction and performance test of the machine components for effective and efficient planting of crops.

Chapter One introduced the research work with the highlight of significance of the study. The chapter also highlighted the statement of problems, aim and objectives of the research and justification.

Chapter Two reviewed the existing planters and methods ranging from manual, animal, tractor drawn as well as self-propelled planters. Special highlight on specific types of mechanical planters were reviewed. Also, the specification of planters alongside with pictures were presented.

Chapter Three discussed the materials and methods adopted in achieving the research objectives. The four-row animal drawn precision seed planter was designed and fabricated alongside with the cross bar arranged in a row. This section equally showed the performance evaluation procedures where selected experimental variables such as planting speed, seed quantity and planting depth were considered and their experimental layout were duly stated. Performance indicators such as plant spacing, seed depth, germination count, seed rate, field efficiency and field capacity were considered. Analysis of variance (ANOVA) was adopted for analysis of data obtained from field experiment.

Chapter Four showed the results and discussion of the field experiment where maize seed was planted in accordance with experimental procedures. The result showed that planting with 50 % hopper full with seed at a planting speed of 0.8 m/s and 2.5 cm planting depth recorded highest mean field efficiency of 86.9 % which is significantly different from the other results obtained. Mean field capacity of 0.59 ha/hr, seed rate of 22.3 kg/ha, and highest germination count of 100 plant stand were recorded.

Chapter Five summarized, concluded the research work carried out and provide recommendation for effective use and possible modification of the machine.

5.2 **Conclusion**

The development and performance evaluation of four-row animal drawn precision seed planter was done in the Department of Agricultural and Bio-resources Engineering, Ahmadu Bello University, Zaria. The planting speed, hopper seed quantity and planting depth influenced the field performance of machine.

The seed spacing was influenced by planting speed but not affected by seed hopper quantity and planting depth. The best spacing was achieved at moderate planting speed.

Germination count and seed delivery rates were also affected by planting speed, seed hopper quantity and planting depth.

Better germination and seed delivery rate were achieved with decreasing planting speed and planting depth as well as increasing seed hopper quantity.

Field capacity and Field efficiency were as well influenced by planting speed, seed hopper quantity and planting depth.

Field capacity increases with increase in planting speed, planting depth and moderate seed hopper quantity. The Field efficiency increases with decrease in planting speed, moderate hoper quantity and increase in planting depth.

Lastly, the seed drop per hill neither influenced by planting speed, seed hopper quantity nor planting as average seed drop across all the treatment is one seed.

It is therefore concluded that planting at 0.6 and 0.8 m/s, with 50 and 100 % seed hopper capacity and 2.5 cm planting depth result in maximum planting performance. With these combinations, optimum seed spacing, seed depth, germination count, seed rate together with high field efficiency and field capacity could be obtained.

5.3 Recommendations

For effective use and possible modification of the four-row planter, the following are recommended

1. Planting operation should further be performed on a flat slightly tilled soil.
2. Aluminum or plastic seed plate with no casing for further research should be attempted.
3. Longer traction bars or rods should be welded on the circumference of the wheels for effective gripping to the soil.
4. Adoption for planting a graded seed such as soya beans and cowpea should be attempted.
5. Other power sources such as the use of motorcycle and tricycle should be attempted.

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Appendices

Appendix A1

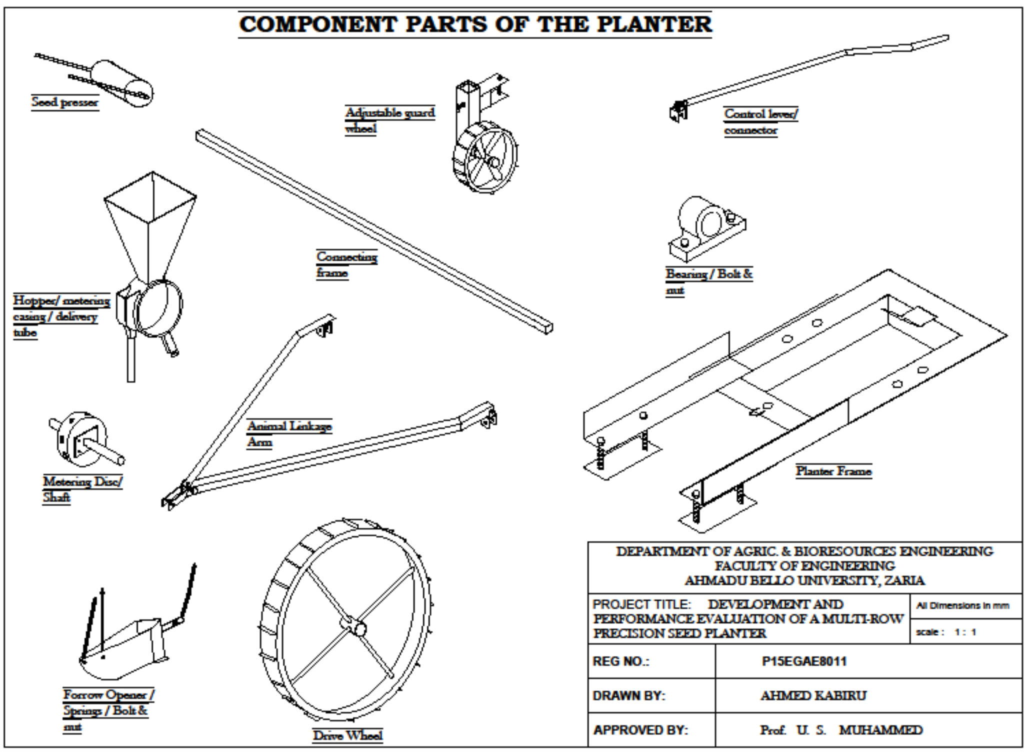


Fig. A1: Component Part of the Planter

Appendix A2

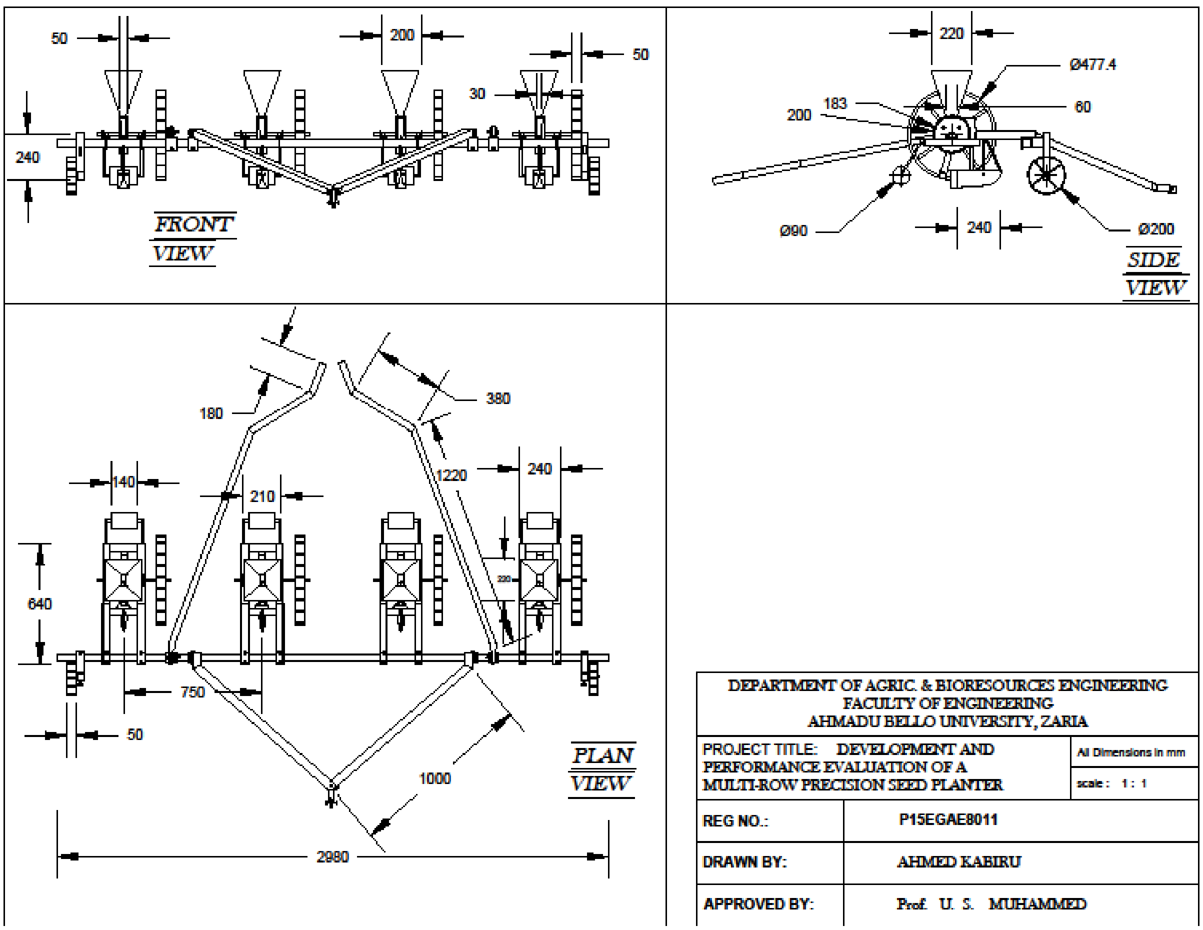


Fig. A2: Orthographic View of the Planter

Appendix A3

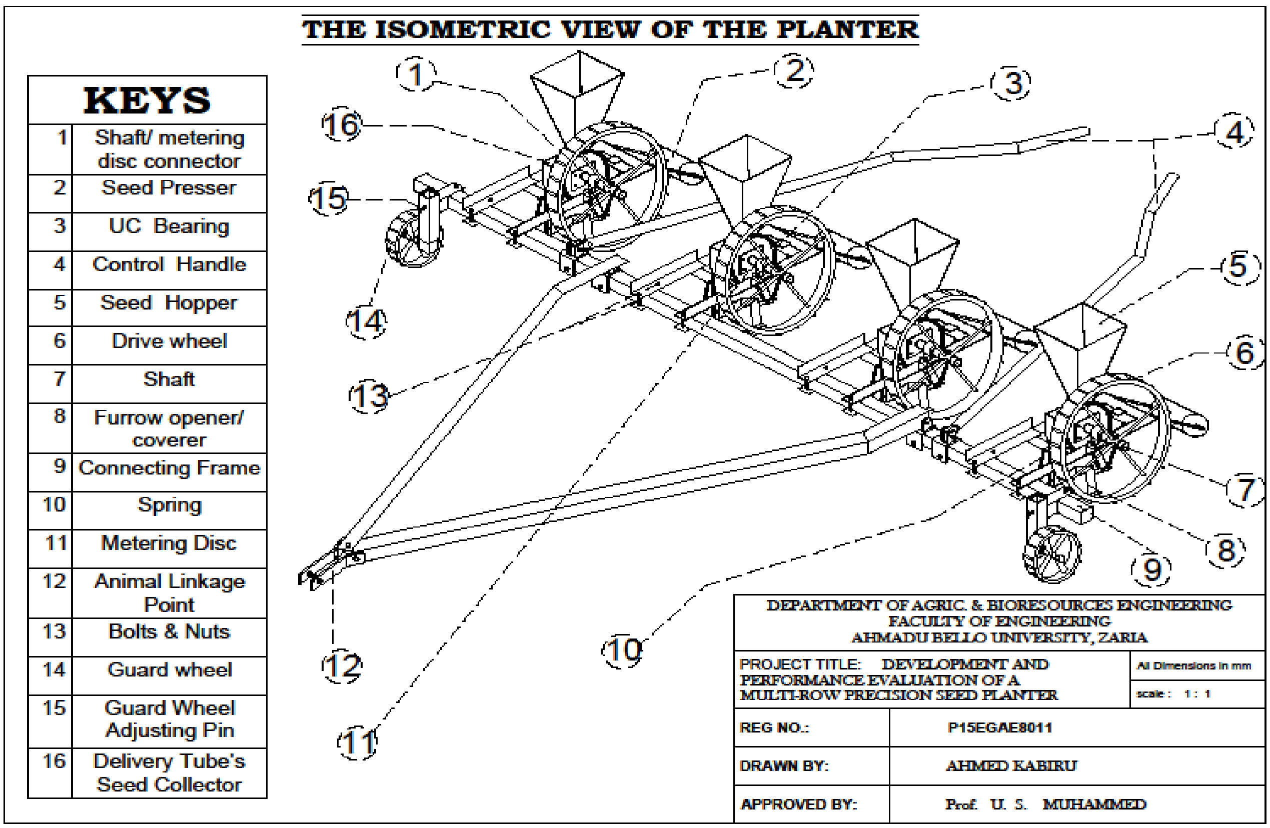


Fig. A3: Isometric View of the Planter

Appendix B

Some Physical Properties of Sammaz 14

Table B1

Physical Property	Unit	No of Observation	Mean Value	Min. Value	Max. Value	SD	CV
Length, L	mm	50	10.69	6.27	12.91	1.47	13.79
Width, W	mm	50	8.03	5.14	9.81	1.02	12.7
Thickness, T	mm	50	3.97	3.01	4.83	0.4	10.03
Equivalent diameter, De	mm	50	7.27	5.45	8.36	0.7	9.68
Surface area, A	cm^2	50	1.53	0.86	2.02	0.27	0.18
1000 Mass, M	g	10	241	224	258	12.26	5.09
Static angle of repose, υs	(^{o})	10	28.67	25.94	29.87	1.61	5.60

Table B2: Coefficient of Friction

Wood		5	0.52	0.47	0.58	0.04	7.78
Plastic		5	0.41	0.38	0.45	0.03	6.66
Metal		5	0.40	0.38	0.42	0.02	4.58

Plate C3: Seed Length Determination

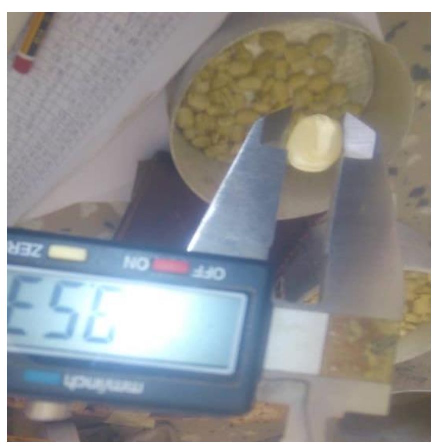


Plate C4: Seed width Determination

Appendix C
Independent Variable and Experimental Layout

Table C1: Independent Variable

Variables	**Levels**
Working speed	S_1, S_2 and S_3
Seed Quantity	W_1, W_2 and W_3
Planting Depth	D_1 and D_2

Table C2: Experimental Layout

Replication I

S1W1D1	S1W1D2	S1W2D1	S1W2D2	S1W3D1	S1W3D2
S2W1D1	S2W1D2	S2W2D1	S2W2D2	S2W3D1	S2W3D2
S3W1D1	S3W1D2	S3W2D1	S3W2D2	S3W3D1	S3W3D2

Replication II

S3W2D2	S3W3D1	S3W3D2	S2W1D1	S2W1D2	S2W2D1
S1W2D2	S1W3D1	S1W3D2	S3W1D1	S3W1D2	S3W2D1
S2W2D2	S2W3D1	S2W3D2	S1W1D1	S1W1D2	S1W2D1

Replication III

S3W3D2	S2W1D1	S2W2D1	S3W3D1	S3W2D2	S2W1D2
S1W3D2	S3W1D1	S3W2D1	S1W3D1	S1W2D2	S3W1D2
S2W3D2	S1W1D1	S1W2D1	S2W3D1	S2W2D2	S1W1D2

A layout of $3 \times 3 \times 2$ factorial experiment involving three planting speed (S1, S2, S3), three seed quantity (W1, W2, W3) and two planting depth (D1, D2) arranged in a randomized complete block design (RCBD), with three replications.

Appendix D

Design Parameters

(i) **Weight of the Planter**

Weight of the planter component acting on the wheel = $W_m + W_h + W_{fr} + W_c + W_b + W_{ala}$...3.11

Where W_m = Weight of the metering plate

W_h = Weight of the hopper

W_{fr} = Weight of the frame

W_c = Weight of the metering casing

$W_b = W_{hsp} + W_g$

W_b = weight of connecting bar

W_{hsp} = weight of hollow square pipe

W_g = weight of gravel

W_{ala} = weight of animal linkage arm

$$W = \ell \times V \times g \quad \text{(Ei)}$$

Where ℓ= density of the material

V = volume of the material

But $\ell_m = 960 kg/m^3$ $\ell_h = \ell_{fr} = \ell_c = \ell_b = 7850$ $kg/m^3 \ell_g = 1346$ kg/m^3

Where ℓ_g = density of gravels = 1346 kg/m^3

$V_m = \pi h (R^2 – r^2) = 3.142 \times 0.04 \times (0.0965^2 – 0.0125^2) = 0.001151$ m^3

$V_h = 2 \times (A_l \times t + A_s \times t) = 0.000214$ m^3

Where A_l = area of the large plate of the hopper (m^2)

A_s = area of the small plate of the hopper (m^2)

t = thickness (m)

Area of the hopper plate (A) = $2[\frac{1}{2}(a_l + b_l)h] + 2[\frac{1}{2}(a_s + b_s)h]$

Where a_l = length of the small side of the large plate

b_l = length of the large side of the large plate

a_s = lengtjnbh of the small side of small plate

b_s = length of the large side of the small plate

h = height of each plate

$$V_{fr1} = V_l + V_b \quad \text{(Eii)}$$

$V_{fr1} = 2[L_l(2B_l)T_l] + 2[L_b(2B_b)T_b] = 2[0.32(2\times0.0508)0.003] + 2[0.165(2\times0.0508)0.003]$

$V_{fr1} = 0.000295656\ m^3$

$V_{fr2} = 2[L(2B)T] = 2[0.3(2\times0.0508)0.003] = 0.00018288\ m^3$

$V_{fr3} = 2[L(2B)T] = 2[0.2(2\times0.0508)0.003] = 0.00012192\ m^3$

$V_{ala} = 2[L(2B)T] = 2[1(2\times0.0508)0.003] = 0.0006096\ m^3$

$V_{fr} = V_{fr1} + V_{fr2} + V_{fr3} + V_{ala} = 0.001210056 m^3$

$V_{fr} = 0.001\ m^3$

$V_c = \pi R^2 h - \pi r^2 h = 3.142 \times 0.05\ (0.1045^2 – 0.0975^2) = 0.000222\ m^3$

$V_c = 0.000222\ m^3$

$W_b = W_{hsp} + W_g$

$V_{hsp} = [(0.0508 \times 0.0508) – (0.0478 \times 0.0478)] \times 2.98 = 0.000881484\ m^3$

$V_g = [0.0478 \times 0.0478] \times 2.98 = 0.0068088232\ m^3$

$V_b = 0.000881484 + 0.0068088232$

$W_m = 960 \times 0.001151 \times 9.81 = 10.84N$

$W_h = 7850 \times 0.000214 \times 9.81 = 16.48N$

$W_{fr} = 7850 \times 0.001 \times 9.81 = 77.01N$

$W_c = 7850 \times 0.000222 \times 9.81 = 17.11N$

$W_b = [7850 \times 0.000881484 \times 9.81] + [1346 \times 0.0068088232 \times 9.81]$

$W_b = 67.88N + 89.91N = 157.79N$

The weight (load) on the wheel of a single planter (W_1) = 10.84 + 16.48 + 77.01 + 17.11

W_1 = 121.44 N = 12.379 kg

The total force exerted on the wheel and furrow opener of the four planter (W_4) = 121.44×4 + 157.79 = 485.76 + 157.79

W_4 = 643.55 N

But for single planter = 643.55 ÷ 4 = 160.89 N = 16.40 kg

(ii) Determination of the Torque on the Metering Plate

The torque on the metering plate is obtained below

$T_m = F_{md} \times r_{md}$

Where F_{md} = force produced by the metering plate

r_{md} = radius of the metering plate

$T_m = 10.84 \times 0.0965$

$T_m = 1.046\ Nm$

For the four metering plates we have T_m = 4.184 Nm

(iii) Draft requirement for the planter

Total Draft requirement for the planter = $D_f + D_w$ (Eiii)

$$D_f = R_s \times A_f \times g \quad \text{(Eiv)}$$

Where D_f = draft of the furrow opener

R_s = soil resistance

A_f = area of the furrow opener

g = acceleration due to gravity (9.81 m/s^2)

Considering 1.5 cm soil depth

$$D_f = 0.385 \times (24 \times 1.5) \times 9.81$$

$$D_f = 135.97 \text{ N}$$

For the four planter D_f = 543.88 N

(iv) Force Required to Overcome Soil Resistance

$F_{rs} = R_s \times A_c \times g$

Where R_s = soil resistance

A_c = contact area of the wheel

$F_{rs} = 0.385 \times (5.08 \times 1.5) \times 9.81$

F_{rs} = 28.78 N

For the four planter F_{rs} = 115.12 N

3.5.5 Rolling resistance of the wheel

$$R_r = \left(\frac{1.2}{c_n} + 0.04\right)W \quad \text{(Ev)}$$

But $c_n = \frac{CI \times b \times d}{W}$

Where W = total force/load exerted on the wheel (N)

CI= cone index (N/m^2)

b = width of the wheel (m)

d = depth of the wheel in the soil

Considering cone index for heavy clay soil which is 0.735 kg/cm^2, wheel depth of 1.5 cm and the wheel width (b) to be 5.08 cm

$$c_n = \frac{CI \times b \times d}{W} = \frac{0.385 \times 5.08 \times 1.5}{16.40}$$

$$c_n = 0.18$$

$R_r = (\frac{1.2}{0.18} + 0.04)\ 160.89$

$R_r = 1084.39$ N

For the four planters = 4337.56 N

(v) Total Forces Required to Push the Planter

Total Force (F) = $D_{fr} + F_{rs} + R_r$

Where D_{fr} = Draft of furrow opener

F_{rs} = Force required to overcome soil resistance

R_r = Rolling resistance of the wheel

F = 543.88 + 115.12 + 4337.56

F = 4996.56 N

(vi) Torque on the Wheel

$T_w = F \times r_w$

Where r_w = Wheel radius

$T_w = 4996.56 \times 0.2387$

$T_w = 1192.68$ Nm

3.5.8 **Total Torque**

$T = T_w + T_{md}$

T = 1192.68 + 4.182

T = 1196.862 Nm

(vii) Angular Velocity

$$w = \frac{2\pi\eta}{60} \qquad \text{(Evi)}$$

where ŋ = Number of revolution (rpm)

w = angular velocity

Considering ŋ for 1 revolution

$$w = \frac{2 \times \pi \times 1}{60}$$

w = 0.105 rad/sec

(viii) Power Required to Push the Planter

The power required to push the wheel of the planter is determined as expressed below;

$$P = T \times w \qquad \text{(Evii)}$$

Where P= power required to push the planter

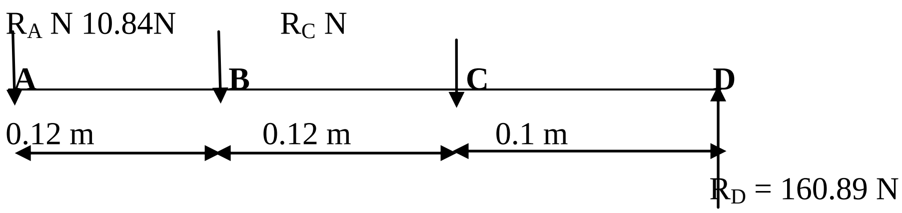
T = torque on the shaft (Nm)

w = angular velocity (rad/sec)

P = 1196.862× 0.105

P = 125.67 watt

(ix) Determination of the Bearing Reactions



The total load on the wheel = 160.89 N

Summing vertical forces = 0

$160.89 - R_C - 10.84 - R_A = 0$

$R_A + R_C = 150.05$ N ………………..i

Taking moment about R_D

$-R_A \times 0.34 - 10.84 \times 0.22 - R_C \times 0.1 = 0$

$0.34R_A + 0.1R_C = -2.3848$ N ………..ii

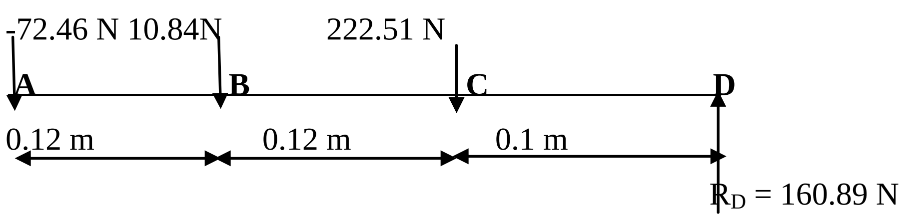
By eliminating R_C in equation i and ii above

$R_A = -72.4575$ N

Substituting R_A into equation i

$R_C = 222.51$ N

(x) Determination of Maximum Bending Moment



Where R_D = reaction by the wheel

Weight of the metering device = 10.84 N

At point D

BM = 0 Nm

At point C

BM = -160.89 × 0.1 = -16.089 Nm

At point B

BM = -160.89 × 0.22 + 222.51 × 0.12 = -8.69 Nm

At point A

BM = -160.89× 0.34 + 222.51 ×0.24 + 10.84 × 0.12 = 0.0006 Nm

Therefore, the maximum bending moment M_b = 0.0006 Nm

The torsional moment of a single planter M_t = 299.22 Nm

(xi) Determination of the shaft diameter

The shaft size was selected using the relationship given by (Kurmi and Gupta 2006) as;

$$d^3 = \frac{16}{\pi \tau_s}\sqrt{(K_b M_b)^2 + (K_t M_t)^2} \quad \text{(Eviii)}$$

Where; d = shaft diameter

K_b and K_t = combine shocks and fatigue factors applied to bending and torsional moment respectively

M_b and M_t = bending and torsional moment (N/m^2)

τ_s = allowable stress of the steel shaft (N/m^2)

Allowable shear stress for shaft without keyways, τ_s = least value of 0.3 yield strength and 0.18 ultimate strength of the shaft material (Kurmi and Gupta 2006)

The material selected for the shaft is mild steel (C1040) with ultimate and yield strength of 770 and 580 MN/m^2 respectively.

0.3(580) = 174MN/m^2

0.18(770) = 138.6 MN/m^2

The smaller value is 138.6 MN/m^2 and further reduced by 25 % due to the presence of key way

(1 - 0.25) × 138.6 = 103.95 MN/m^2

Allowable shear stress for shaft, τ_s = 103.95 MN/m^2

K_b= 1.5 to 2.0

And K_t = 1.0 to1.5

$$d^3 = \frac{16}{\pi \times 103.95 \times 10^6}\sqrt{(1.5 \times 0.0006)^2 + (1.0 \times 299.22)^2}$$

d_s = 0.0253 m

d_s = 25.3 mm

Therefore, a shaft of 25 mm diameter was selected.