Design and Fabrication of a Manual Bean Planter

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Abstract

Manual seeding of beans using hand hoes or machetes is laborious, time-consuming, expensive, and inefficient. Due to non-uniformity, optimization is reduced leading to low productivity. The design and fabrication of a two-row push-type manually operated bean seeder was to alleviate this challenge, more so to reduce drudgery, improve timeliness, reduce cost of seeding, and increase efficiency. The design took into consideration the main functions of a seeder such as furrow opening, seed dropping, soil covering and forward motion. The drive mechanism was achieved by a drive wheel with spikes for traction. A shaft attached to the wheel operates the metering devices for seeds and fertilizer. The seeds are metered one at a time by pick-up cups welded on the periphery of a circular plate attached to a circular plate. The seeds are dropped into the furrow through a delivery chute. Granular fertilizer metering mechanism was achieved by a roller drill type while furrow opening, soil cover mechanism and stability of this seeder was incorporated in the design. Laboratory and field tests of the prototype revealed that the seeder is best operated at 0.3 to 0.6 m/s, average seeding depth of 2 - 5 cm and efficiency of 60-70% was recorded.

Keywords: Manual, seeder, Fabrication, furrow-opener, productivity.

1.0 Introduction

Agriculture sector in Kenya is the fundamental part of the economy contributing 25% of the total Gross Domestic Product (GDP), and another 27% indirectly. The sector employs over 40% of the total population and over 70% of the rural people. In June 2008 Kenya adopted the Kenya Vision 2030 as a new blueprint for Kenya's development. aiming at transforming Kenya into "a newly industrializing, middle-income country providing a high quality of life to all its citizens in a clean and secure environment". In the Vision, agriculture is identified as a key sector in achieving the envisaged annual economic growth rate. This shall be achieved through transformation of smallholder agriculture from subsistence to an innovative, commercially oriented, and modern agricultural sector (GOK, 2008). However, smallholders have relied heavily on rain-fed and poorly mechanized production systems (GOK, 2009). Agricultural mechanization is the application of tools, implements and powered machinery as inputs to achieve agricultural production (Clarke and Simalenga, 1997). The aim of mechanization is to increase output, reduce costs, or both as well as reduce drudgery of farm operations. Hence the need to increase mechanization status of the smallholder in Kenya, who account for 75% of the total agricultural output and 70% of marketed produce (ASDS, 2010). In horticulture sub sector, smallholders produce 94% of vegetables for local and export markets, and French beans, which are produced for fresh market or for canning, is no exception (GOK, 2017). For the producers focused on higher incomes and really market oriented production system, production is staggered, and sowing is done every 2 - 3 weeks to achieve year-round production and maximize output during the peak period of October to May. This call for proper timing of all operations and hence the need to mechanize planting to reduce planting lead time. Recommended spacing for French beans is 30 cm between rows and 10 - 15 cm between plants. A seed rate of 30 - 35 kg per acre is recommended for ultimate plant population and productivity per unit area (SHEP UP, 2015). Currently, the sowing is done manually; the planting furrows are made using hand hoes, and seed and basal fertilizer is placed in the furrow by hand. Generally, it takes 20 people to plant 1 acre of French beans. This method is quite laborious, time consuming, costly, and inefficient. Sometimes there are incidences of labour shortages making timeliness of operation impossible which results in loss of income for the farmer.

Smallholder producers should adopt efficient production systems geared toward cost effectiveness in order to attain higher incomes from the investment. Consequently, there is need to introduce improved planting methods for enhanced timeliness, reduction of sowing labour requirements and overall efficiency in French bean production. Based on the foregoing, the development of a bean seeder was undertaken. The objective of this work was to design, fabricate and test a push type, two-row bean seeder machine appropriate for small scale French bean planting.

2.0 Materials and Method

2.1 Philosophy of the Design

The seeder was conceived as a low cost, portable, hand-operated, push-type, two-row machine for precise placement of single seeds of French beans and other related species of beans in the soil during planting. It was intended to perform the following essential tasks:
i) Move forward by pushing
ii) Open furrows in pulverized soil in prepared seedbed
iii) Meter one or two seeds correctly,
iv) Drop the seeds in the opened furrow uniformly spaced
v) Spread a thin layer of granular fertilizer in the furrow
vi) Cover the furrow with a thin layer of soil and lightly press the soil
These tasked were to be carried out simultaneously. The material used to fabricate the machine was mild steel due to its low cost and wide availability.

2.2 Design Considerations

i) Spacing: The single row spacing of 30 cm between rows and 10 -15 cm between plants was considered at one seed per stand in the design of the drive wheel and seed metering mechanism. The drive wheel was to cover 1 meter in one revolution. To achieve the desired circumference of 1meter in one revolution, the following formular was used;

$$C = \pi D$$

Where, D is the external diameter of the wheel

ii) Seed metering device: The seeder was conceived as a precision planter and so seed picking and dropping of seeds were critical parameters to consider. Being operated by the drive wheel, the metering device was to meter 6 to 10 seeds in one revolution of the drive wheel. Axial dimensions of selected French beans were used to design the metering device.

3.0 Results

3.1 Machine Parts Description

i) Drive wheel: The drive wheel was built from a 1034 mm long mild steel flat bar of 50 mm width and 6.0 mm thickness. The effective external diameter of 326 mm was achieved after rolling the bar and welding the ends. Stability of the wheel was achieved by 4 spokes of 12 mm diameter welded on the internal circumference. Traction of the wheel was achieved by 16 spikes made from MS angle bar of 50mm and 4.5mm thickness cut into 40mm length pieces welded along external circumferential surface of the wheel. A bush made of brass was installed at the centre. The bush had a bore of 12 mm diameter for installation of a drive shaft.

ii) Furrow opener: A full runner type furrow opener was designed and fabricated from 2 pieces of sheet metal measuring 150 mm x 50 mm and 4.5mm thick mounted on a handle made from a square hollow bar of 15 × 15 × 300 mm and thickness of 2mm.

iv) Seed hopper: Seed hopper was fabricated from a sheet metal of 1mm thickness to accommodate the metering device and seeds. It was fitted with a chute to deliver the seeds into the opened furrow. One hopper was designed to hold about 700 seeds. The target is to plant 1 seed per drop at a spacing of 30 cm by 10 - 15 cm from one seed to the other. Since there are two hoppers, they hold 1400 seeds with the view to plant about 0.02 ha before refill.

v) Delivery chute: is made from sheet metal of thickness 1.0 mm folded and then spot welded onto the front side of the hopper. The seed chute extends 60 mm below the hopper to facilitate delivery of the seeds into the opened furrow.

vi) Seed metering mechanism: A disc of 100 mm diameter was grooved at 30^0 with 6 equidistance grooves of 10 mm radius. The grooves hold the seed pick up cups made from a 20 mm long 12 mm solid bar with grooves of 17, 9 and 8 mm in length, width, and depth respectively.

vii) Basal fertilizer application mechanism: The mechanism consists of a hopper, metering device and delivery chute. The hopper is made from 1.2 mm sheet metal bent and welded to form a half-fluted shape at exit side fitted with two delivery tunnels opened by an adjustable sluice gate. The inside was rounded to reduce turbulence as the fertilizer granules travel to the metering device. The fertilizer metering device was made from a Poly Vinyl Siloxane (PVS) roller with grooves of 2.5mm deep and 16 mm long and 6 mm wide.

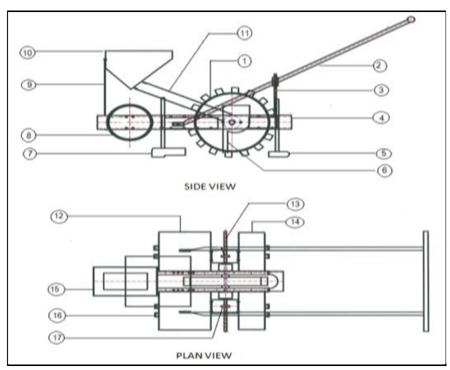
vii) Soil coverer: A soil covering device is provided to cover the furrow and compact the soil lightly over the seed. Soil cover device was made from sheet metal formed to the desired shape and the handle from a square hollow bar of 15 × 15 × 300 mm.

viii) Frame: The frame was made to hold all parts effectively during operation and storage of the machine. It was made from sheet metal of thickness of 3.2 mm and brackets made to fix the attachments onto the main frame.

ix) Front wheel: The front wheel was built designed to provide stability during operation. It was made from made from a sheet metal of 628mm long 100mm and 4.5mm thickness rolled and welded to form a diameter of 200 mm and width of 100 mm. A reinforcement circular plate of 200mm diameter and 6 mm thickness, with 4 holes of 50mm diameter cut out equidistance at each quadrant was welded on to the internal circumference.

x) Handle: The handle was made from two hollow pipes of 2 mm thickness. Two longitudinal parts were made from a hollow pipe of 19 mm diameter and 1200 mm length, while the lateral part was made from a hollow pipe of 32 mm diameter and 600 mm length. The longitudinal pipes were welded onto the lateral pipe.

Plate 1: The developed prototype machine



1	Drive wheel
2	Handle
3	Height adjusting arm
4	Main frame (Rear)
5	Soil coverer
6	Seed delivery cute
7	Furrow opener
8	Front wheel
9	Fertilizer hopper support
10	Fertilizer hopper
11	Fertilizer delivery chute
12	Front wing
13	Drive shaft
14	Rear wing
15	Main frame
16	Furrow opener fixing bracket
17	Seed hopper
Part Nos.	**Description**
Dept. of Agricultural Engineering, Ministry of Agriculture, Livestock and Fisheries, Nairobi, Kenya	
Title	Push Type Two-Row Manual French Bean Seeder
Designed by	NYAGA Alice and OTSUKA Kanji
Drawn by	NYAGA Alice
Checked by	OTSUKA Kanji

Figure 1: Plan and side view of the prototype Machine

3.2 Laboratory Test Results

The seed sizes used in the tests were generally uniform with the major, minor and intermediate diameters of 10 - 16 mm, 6 – 8 mm and 5 – 7mm, with a standard deviation of between 0.3 and 0.9 for all the 3 varieties used. The test method was adopted from Regional Network for Agricultural Machinery Test Codes and Procedures for Farm Machinery (2016).

Laboratory tests done showed that the machine metered the seeds with an efficiency 80%. The picking efficiency was also evaluated, and the results showed a satisfactory performance. From the data collected, it was evident that one cup performed excellently, with no miss and no double pick, while other 3 cups performed well with no miss. Unfortunately, one cup was found to have the highest probability of miss, with 40% probability of miss. Another 4 cups had no probability of double pick.

The basal fertilizer application was tested in the laboratory. The fertilizer metering efficiency were 1.5g and 1.2 g from the right and left side rollers, respectively. This was deemed satisfactory considering the recommended requirement for 1 g per hill.

3.1 Field Test Results

The field tests were done to evaluate the slip of the prototype planter and the seed rate and the operation speed.

Slip: The method for slip measurement is as given by Ajit, 1993 and Brewer, 1988. The distance covered by the drive wheel in 10 revolutions was measured using a tape measure and found to be 12.1 metres.

The circumference of the wheel , C=πD =3.14 × 0.326 m = 1.023m;

Percentage slip (Ƞ) is given by the formula,

$$Ƞ = \frac{(L-C)}{C} \times 100 = \frac{(1.21-1.02)}{1.02} \times 100 = 18.6\%$$

where, Ƞ =percent slip
L = distance covered by the wheel in 1 revolution
C = circumference of the drive wheel.

The theoretical interval of seeding(s) is given by

$$s = \frac{C}{6\left(\frac{100-\eta}{100}\right)} = \frac{1.023}{6\left(\frac{100-18}{100}\right)} = 0.14\ m$$

where, S = theoretical interval of seeding
C = circumference of the drive wheel
6 = Number of seed pick-up cups
Ƞ = % slip

The actual spacing between seed dropping on the field showed results in the range of 150 ~ 180 mm and row spacing gave an average of 300 mm.

3.1.2 Seed rate: From the parameters of the machine, seed rate was found to be comparable to the recommended seed rate of 30-35kg per acre (SHEP UP, 2015)

Parameters considered include:

a) Effective diameter of drive wheel = 0.326 m
b) Distance covered by one revolution = π × 0.326 = 1.023 m
c) Area required for one seed = row spacing x seed spacing = 0.3 × 0.15 = 0.045 m^2
d) Total number of seeds per hectare = 10,000/0.045 = 222,222
e) Taking the average weight of the seeds to be 0.35g, the seed required per hectare = 222222 × 0.35/1000 = 77.77 kg/ha

Table 1: Specifications of bean seeder

Parameter	Specifications
Type of seeder	Manually operated, push-type
Number of rows	2
Nominal working width	30 cm
Hill to hill distance	10 cm ~ 15cm
Seed for which seeder is suitable	Oblong and oval
Suitable crops	French beans, field beans
Overall length	1430 mm
Width	600 mm
Height	850 mm ~ 950 mm
Overall weight	33 kg
Metering mechanism	Circular plate with cups
Suitable travelling speed	0.3– 0.6 m/s
Fertilizer facility	1 hopper
Hopper capacity- seed	1.4 kg
Hopper capacity- fertilizer	5 kg
Type of furrow opener	Full runner type
Type of covering mechanism	Leaf plate type

4.0 Discussion

The material selection for fabrication of the seeder was Mild Steel due to its availability and affordability. The objective of the project was to deliver an effective French bean planting machine that is affordable to smallholder French bean producers. The final total weight of the machine was 33 kg. This may be slightly difficult to operate for weak persons and hence the need for more work to make the machine lighter and easier to operate. The prototype bean planter is an improvement over manual planting with hoes and hand placement of seed and fertilizer. With this device, labour requirement for planting one acre was reduced from 20 people to 4 (about 80% labour reduction), planting depth and germination was more uniform, plant population is maximized, more output is guaranteed, and drudgery is greatly reduced. The device is easy to handle, adjust, operate and transport to the field, however, it should be kept in horizontal position during operation and operating speed should be maintained at 0.4 - 0.6 m/s. At higher speeds, the probability of “miss” increases.

The machine may be adapted for planting other species of beans after changing the seed metering device to suit the axial dimensions of the selected bean variety. The option of planting without the basal fertilizer application is also feasible since the fertilizer application mechanism is detachable and the rest of the machine works efficiently.

5.0 Conclusion

The prototype machine fabricated can substitute the hand hoes in French bean sowing and increase efficiency of seeding. The seeder is affordable and can easily be operated with minimum skills.

6.0 Acknowledgement

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