Nigerian Journal of Engineering Science Research (NIJESR).
Vol. 5, Issue 2, pp.73-81, June, 2022

ISSN: 2636-7114
*Journal Homepage: https://www.iuokada.edu.ng/journals/nijesr/*

# Development and Performance Evaluation of a Hand-Pushed Fertilizer Application Equipment

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**Manuscript History**
*Received: 10/05/2022*
*Revised: 12/06/2022*
*Accepted: 25/06/2022*
*Published: 30/06/2022*

**Abstract:** *Available fertilizer applicators in Nigeria are mostly tractor mounted meant for large scale farming. Conventional application of fertilizers for small scale farming are usually by manual means through broadcasting and band application since it would be uneconomical to used large scale applicator for fragmented farms. These manual methods are tedious and time consuming demanding high human effort besides resulting in uneven spreading of fertilizer. The objective of this study is to develop a simple but effective and inexpensive hand-pushed fertilizer application equipment that would address the problems encountered by the peasant farmers as well reduces field wastage occasioned by manual application system for optimum crop growth. Major components of the applicator are hopper, frame, agitator, spreading disc and flow rate control mechanism. The applicator was evaluated both in the field and laboratory using Single Super Phosphate (SSP) fertilizer. Results obtained shows that the effective field capacity, effective width, effeciency of the applicator and its spreading capacity ranges from 4.77 – 8.34 ha/hr, 0.94 – 1.22 m, 90.67 % and 350-28 - 569.88 kg/hr, respectively. It was also observed that the effect of swath width, operating speed and the amount of fertilizer deposited were highly significant on the effective field capacity and efficiency of the developed applicator. Similarly, the developed fertilizer applicator was noted to have addressed most of the challenges of manual fertilizer application. The estimated cost of production of the fertilizer applicator is N18,250:00.*

**Keywords:** *Application, Field Efficiency, Field Capacity, Operating Speed, Swath Width*

## INTRODUCTION

Increased agricultural productivity usually comes as a result of the effective adoption of improved agricultural technologies. Fertilizer application is one of the important factors for optimum crop production and increased yield (Rick *et al.*, 2015; King *et al.*, 2020; Gross and Glacer, 2021). Majority of Nigerian peasant farmers apply inorganic fertilizer for their agricultural production manually by direct band placement and/or manual broadcasting methods (Singh and Singh, 2014; Sengottaian *et al.*, 2019). Besides being unhygienic and low efficient, the method is labour intensive, wasteful and relatively time consuming. Similarly, the application rate per unit area is not uniform (Davis *et al.*, 1997; Thompson *et al.*, 2020). Broadcasting does not also allow applied fertilizers to the target crops as about 21% of its nitrogen were either lost to the atmosphere or applied to unwanted crops (Lague *et al.*, 1994; Sahu *et al.*, 2020).

In attempt to solve the aforementioned problems, varieties of fertilizer applicators were developed locally while others were imported and distributed to farmers at subsidized rates by various tiers of government in Nigeria. However, most farmers could not afford or operate them due to high cost, complexity in design and heavy weights that requires higher capacity power source to operate (Ojeniyi, 2000; Mbatha *et al.,* 2021). Similarly, most of the locally developed applicators could not function to the satisfaction of the farmers. Farmers were also faced with many problems and health challenges such as fatigue, tiredness, muscular and spinal cord pains etc. in the course of using such fertilizer applicators, possibly because the causes of such challenges were not taken into consideration. The objectives of this study, therefore, was to develop a simple but efficient and affordable small-scale fertilizer applicator that would simplify and maintain uniform fertilizer application for optimum crop growth in order to alleviate the problems and challenges encountered by the peasant farmers.

## MATERIALS AND METHODS

Single Super Phosphate (SSP) fertilizer was used to evaluate the developed fertilizer applicator procured from a local fertilizer dealer in Samaru-Zaria market. A 100 kg capacity weighing balance (WT1000KF, 0.001 Accuracy), digital tachometer (RPM, 0.05% Accuracy), stop watch, 100 m measuring tape, nylon bags and tags were used for the study. Tins to collect samples were also used in determining moisture content of the soil.

### Description of Components of the Hand-Pushed Fertilizer Applicator

The hand-pushed fertilizer applicator consists of frame, hopper, handle and stand, two traction/drive wheels, connecting rod, discharge outlet and metering mechanism (Fig. 1):

Fig. 1 The Developed Hand-Pushed Fertilizer Applicator

#### *Hopper*

The hopper is used as a storage tank where fertilizer to be applied is loaded. It is attached at the top most part of the applicator for temporal holding the fertilizer before being metered onto the spreading disc by gravity. It has a capacity of about 12 kg. Both the hopper and the discharge outlet were made of plastic to minimize corrosion and secured with the frame.

The depth and height of hopper were 50 and 46 mm, respectively with round tapering at the bottom. It was designed to easy movement of manure towards the metering aperture.

*Drive Wheel*

Two drive wheels were provided for the fertilizer applicator both with outer diameters of 400 mm. The length of the shaft of the drive wheel was 48 mm.

*Handle and Stand*

The stand is used to support the applicator at idle state. It is made from 19 mm flat bar. The height of the stand is 128 mm from datum. The handle was made of a square bar of 190 mm length. The length of the holding part of the handle was 19 mm. A 40 mm diameter semicircular component was used to hold the discharge tube rigidly.

*Axle*

The axle is a rod or shaft that rotates the wheels and supports the weight of the applicator. ***Frame –*** the frame is used to support the different components of fertilizer applicator as well as the fertilizer to be applied.

*Metering Device*

The metering device is a major component of the applicator. It meters the required amount of fertilizer and delivers it into the soil through the delivery tube at a predetermined depth created by the furrow opener. The metering device is made up of cast steel material of 240 mm diameter and 4mm thickness.

*Performance Evaluation of the Fertilizer Applicator*

The traditional method for evaluating a field machine uses a series of trays placed on the ground in a line perpendicular to the direction of travel as suggested by Allan *et al.* (2012) and Larry and Allan (2012). One or more passes of the applicator in the same direction deposits the fertilizer in the trays. The fertilizer weight from each tray at 0.6 m interval was collected. It was poured into nylon bags and marked at each calibrations chosen.

*Experiment Procedure*

Weights of 20 kg fertilizer were measured and used for each experiment on a 20 m x 20 m field. After uploading the measured fertilizer into the hopper, the stop watch starts simultaneously as the application begins; effective time, delay and total time were recorded. The swath width was also recorded at intervals and average taken after 3 replications. The independent variable was operator's speed, application rate, average weight of fertilizer applied, and revolutions of the drive wheel. The operator's speed was taken, average and low alongside with three levels of hopper capacity (full, ½ and ¼). Single Super Phosphate (SSP) fertilizer was used for the study. The experiment was laid in Complete Randomized Design (CRD) with three replications in a 3×3×3 factorial experiment. The time taken for the machine to complete fertilizer application operation in the varying speeds using 20 kg of fertilizer at every replicate of T1, T2 and T3 calibrations, was recorded with a stop watch. The application rate was determined in kg/h, using the total effective time in applying the fertilizer during the laboratory evaluation. Moisture content of the experimental field was determined to be 12.4 % (ASAE, 1983). The results were measured and recorded.

*Field Performance Evaluation of the Developed Applicator*

The developed fertilizer applicator was evaluated based on four parameters: field efficiency, uniformity of the application, effective width and effective field capacity.

*Determination of Field Efficiency of the Applicator*

The spreading efficiency of applicator and time required to spread the fertilizer were determined using equations (1) and (2). It gave the actual time required to perform the operation. Time loss due to overlap, turning, loading and unloading the fertilizer were duly accounted as suggested by Khurmi and Gupta. (2005):

$$FE = \frac{T_t - T_d}{T_t} \quad (1)$$

$$T_t = (T_e + T_d) \quad (2)$$

Where;
FE = Field efficiency
$T_t$=Total time required to apply the fertilizer including delayed time, min
$T_e$ = Total effective time in apply the fertilizer, min
$T_d$ = Total delay time required for cleaning, turning, reloading and repair, min

*Uniformity of Fertilizer Application*

The ASAE 341.2 standard collection tray method was used to determe the application uniformity by placing six collection trays at right angle to the direction of travel of the applicator, Lawrence and Yule (2005). Each of the trays has a dimension 0.2 m x 0.2 m x 0.1 m. The distance between the trays was 0.3 m. The sample from each collection tray were collected in polythene bags were weighed and labelled.

*Determination of Effective Width of the Applicator*

The effective width of the fertilizer applicator was measured using a tape after the fertilizer have been spread in three radomly places and the average taken.

*Determination of Effective Field Capacity of the Applicator*

The effective field capacity of the applicator was determined using Equation (3) as recommended by Khurmi and Gupta. (2005) and Bhanagare (2015):

$$C_{eff} = \frac{SW}{10} \times FE \text{ , ha/hr} \quad (3)$$

Where;
$C_{eff}$ = Effective Field Capacity of the fertilizer applicator
ha/h; S = Optimum forward speed of the operator during the operation, km/h
W = Effective swath width of the applicator, m
FE = Field efficiency

## RESULT AND DISCUSSION

The hand-pushed fertilizer applicator was designed and constructed (Fig. 1). It was evaluated both in the laboratory (Fig. 2a) and in the field (Fig. 2b) to determine the uniformity of the applicator, effective width, field efficiency and effective field capacity of the applicator.


Fig. 2 (a) Laboratory and (b) Field Evaluation of the Hand-Pushed Fertilizer Applicator

## Performance Evaluation of the Developed Fertilizer Applicator

The fertilizer applicator was evaluated both in the laboratory and the field:

### *Laboratory Evaluation*

The fertilizer applicator was evaluated at stationary position. It was run at various speeds (Fast Speed, Average Speed and Low Speed) by simply turning the wheels. Results obtained shows that the average spread capacity of the spreader was 33.70 kg/hr at a full hopper flow mechanism setting with low speed, while the lowest average spread capacity was 22.60 kg/hr with fast speed at ¼ full flow rate setting (Table-1). The results obtained indicates that decrease in speed of flow mechanism increases the amount of fertilizer deposited per unit time with a corresponding increase in time taken. At each hopper level and at different rate of drive wheel speed, there was a three-trial test to have an optimal average and hence the result given below:

Table-1 Laboratory Test Result

| S/N | Hopper Capacity (kg) | Rate of speed of Drive Wheel | Average Weight of Fertilizer Collected (kg) | Average Time Taken (s) | No of Drive Wheel Revolution | Machine throughput capacity (kg/h) |
|---|---|---|---|---|---|---|
| 1 | 12 | Fast Speed | 0.242 | 9 | 10 | 25.67 |
| 2 | 6 | Fast Speed | 0.229 | 8 | 10 | 24.29 |
| 3 | 3 | Fast Speed | 0.213 | 7.3 | 10 | 22.60 |
| 4 | 12 | Average Speed | 0.280 | 14.7 | 10 | 29.71 |
| 5 | 6 | Average Speed | 0.259 | 12.3 | 10 | 27.48 |
| 6 | 3 | Average Speed | 0.225 | 13.7 | 10 | 25.05 |
| 7 | 12 | Low Speed | 0.318 | 26.7 | 10 | 33.70 |
| 8 | 6 | Low Speed | 0.301 | 18.0 | 10 | 31.96 |
| 9 | 3 | Low speed | 0.258 | 24.0 | 10 | 29.17 |

*Field Evaluation*

Table-2 shows the results of the field evaluation conducted on the hand-pushed fertilizer applicator.

Table-2 Field Evaluation Results of the Developed Hand-Pushed Fertilizer Applicator

| S/N | Length of Travels (m) | Average Swath width (m) | Time (Sec) | Operation Speed (km/h) | Weight Dropped (kg/h) | Field Efficiency (%) | Effective Field Capacity (ha/h) |
|---|---|---|---|---|---|---|---|
| 1 | 20 | 0.94 | 34 | 0.56 | 569.88 | 90.67 | 4.77 |
| 2 | 20 | 1.11 | 27 | 0.61 | 451.44 | 93.28 | 6.32 |
| 3 | 20 | 1.22 | 22 | 0.72 | 350.28 | 95.05 | 8.34 |

The applicator was also evaluated in the field at a constant length of travel of 20 m with the hopper fully loaded with SSP. It was run at varied speeds of the operator. RNAM (1983) test code was used to determine the speed of travel (km/h) of the operator of known distance (20 m). Results obtained shows that the optimum/peak spread capacity of the applicator was 569.88 kg/h at an operating speed of 0.56 km/h resulting in an average swath width of 0.94 m while the lowest average spreading capacity of 350.28 kg/h was obtained at an operating speed of 0.72 km/h with a swath width of 1.22 m (Table-2). The results obtained indicates an increase in swath width with corresponding decreases in the operating speed of the applicator and decrease in the amount of fertilizer deposited per unit time.

The result obtained, therefore, shows that operating speed was highly significant on the swath width of the developed fertilizer applicator. Higher swath width of 1.22 m recorded may be attributed to the higher operating speed of 0.72 km/h that resulted in less fertilizer being applied. This means that the applicator would be more economical to use the applicator at faster speed where less fertilizer rate is required. However, for crops that requires more fertilizer per unit area, the applicator should best be used at low operating speed in order to have more fertilizer deposited at less swath width. The result obtained also shows that the effect of swath width, operating speed and the amount of fertilizer deposited were highly significant on the effective field capacity presented in Table-2. With more fertilizer deposited per unit area and lower operating speed and less swath with, the tendency is that less area would be covered with fertilizer per unit time. The maximum effective field capacity recorded was 8.34 ha/h at the maximum operating time of 0.72 km/h. The higher mean effective field capacity recorded by the fertilizer applicator could be attributed to wider coverage of fertilizer applied as indicated by the higher swath width obtained.

The result obtained further indicated that the swath width and operating speed were highly significant on the application rate (amount of fertilizer deposited per unit area) of the applicator. It shows that the application rate decrease from 569.88 to 350.28 kg/h with increase in swath width and operating speed (Table-2). Similarly, the result obtained shows that swath width and operating speed were highly significant on the field efficiency of the developed fertilizer applicator as presented in Table-2. The applicator recorded the highest mean field efficiency of 95.05 % at the highest levels of swath width and operating speed indicating that the efficiency of the fertilizer applicator increases with increase in the swath width and operating speed.

## CONTRIBUTION TO KNOWLEDGE

This study has established that the primitive application of fertilizer by most peasant farmers in Nigeria could be improved by the use of the developed simple but efficient hand-pushed fertilizer applicator in order to alleviate the farmer with problems of unhygienic and low efficient, drudgery, wasteful and relatively time consuming as well as the numerous health challenges such as fatigue, tiredness, muscular and spinal cord pains etc. associated with manual application.

## CONCLUSION

A modest and effective hand pushed fertilizer is designed and constructed. It was evaluated both in the field and laboratory to determine it efficiency, swath width field capacity and spreading capacity. Laboratory evaluation of the spreader obtained shows an average spread capacity of the applicator was 3.70 kg/hr at a full hopper flow mechanism setting with low speed, while the lowest average spread capacity was 22.60 kg/hr with fast speed at ¼ full flow rate setting while results obtained from field evaluation indicates an increase in swath width with corresponding decreases in the operating speed of the applicator and decrease in the amount of fertilizer deposited per unit time. The applicator was seen to have uniform and even distribution of fertilizer on all the parameters tested. The performance of the developed applicator was generally noted to be efficient, less labour intensive, easy to operate and relatively less wasteful. It is, therefore, an economic and compact machine which could be used for fertilizer application, especially for small scale farmers. The estimated cost of production of the manure spreading machine is N18,250:00.

## CONFLICT OF INTEREST

The authors declare no competing interest

## ACKNOWLEDGEMENT

This study did not receive any specific grant from funding agencies in public, commercial or not-for-profit sectors.

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## APPENDIX

Appendix 1: Isometric Drawing of the Hand-Pushed Fertilizer Applicator

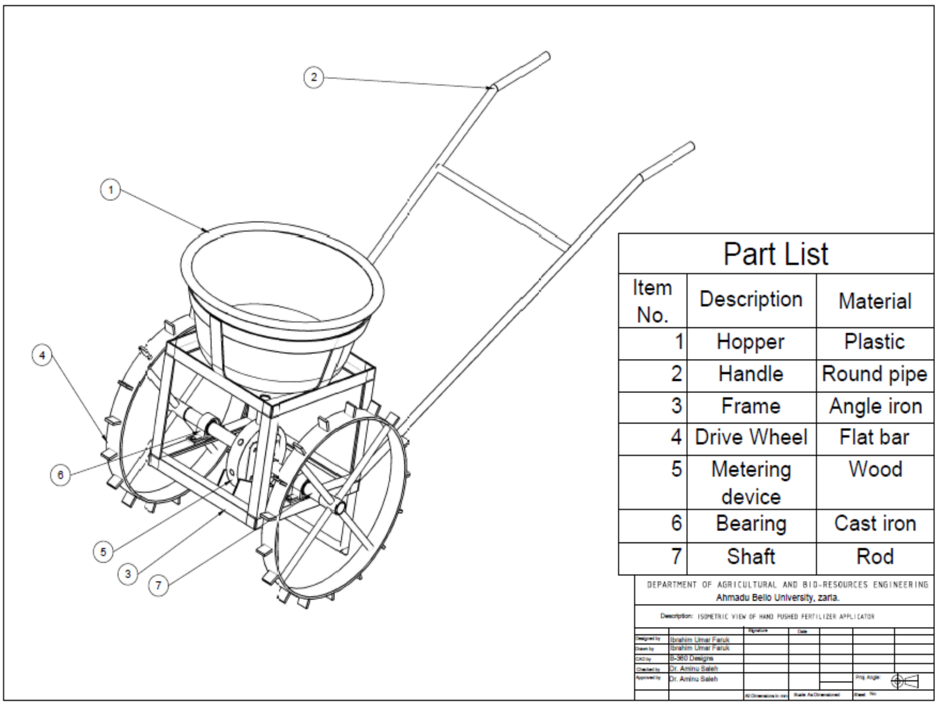


Fig. A1 Isometric Drawing of the Hand-Pushed Fertilizer Applicator