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Research Article

Adaptation and Performance Evaluation of Manual Operated Fertilizer Applicator

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Abstract

Efficient fertilizer application is critical for sustaining crop productivity on nutrient-depleted soils. Improving the effectiveness of chemical fertilizers can be achieved through the development and adoption of advanced, sustainable fertilizer discharge devices. Such innovations offer a more uniform distribution compared to conventional methods, enhancing nutrient use efficiency and contributing to higher crop yields. The fertilizer applicator has an overall height of 1.50m and a total weight of 2.2kg. Its hopper has a volumetric capacity of 18.4m^3, allowing for efficient storage and distribution of fertilizer. The fertilizer tube was constructed from PVC pipe*, the implement was evaluated field capacity, field efficiency and uniformity of fertilizer at proper location. The application rate and hole diameter were determined to investigate performance parameter indicators of the implement. the maximum application rate and time was recorded 311.96 kg/ha and 1.55 ha/hr. respectively. the minimum and maximum application field capacity was recorded when operated by men at 5 cm hole diameter was 46 kg/ha and 1.29 ha/hr. and also the minimum and maximum application rate was recorded 178.53, 294. when operated by women at 3 and 5 cm hole diameter respectively the technology was saved time with 5 diameter sizes but it causes out of recommendation applied per hectare, The 3-diameter hole was saves fertilizer and shows advantage over the both diameter in low application rate the implement was very simple and can produced from locally available materials easy to operate it was low cost and affordable to small scale farmers.*

Keywords

Application Rate, Field Capacity, Field Efficiency and Performance Evaluation

1. Introduction

Adequate fertilizer application techniques and utilization are regarded as key factors in ensuring better yields in the face of degrading soil nutrients. Fertilizers are applied to the soil to supply essential plant nutrients, especially when the native soil nutrients are inadequate to meet the nutritional requirements of crops. According to the United Nations (2015), smallholder farmers supply a large percentage of Africa's total food need. They provide around 80% of the food consumed in both Asia and sub-Saharan Africa [8]. The role and contributions of smallholders' agriculture to food production cannot be over emphasized. Therefore, it is important to ensure that productivity at this level of agricultural production is given the required boost in terms of inputs and efficiency of their farm activities. Consequently, Adequate fertilizer application techniques and utilization are regarded as key factors in ensuring better yields in the face of degrading soil

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nutrients [9]. Fertilizers may be applied before planting, during soil tillage or the seed bed preparation time, during planting and after germination during the active growth period [10]. Fertilizer applications in smallholder production systems are often undertaken manually and this comes with much drudgery [3].

To improve fertilizer, use efficiency has become a national and global concern [1]. One of the ways to improve the efficiency of using chemical fertilizers is through the development and promotion of improved and sustainable fertilizer discharge devices to replace the conventional fertilizer application methods for better uniformity of fertilizer application [11]. Uniformity of fertilizer application refers to the degree of uniform distribution of the fertilizer discharge from the fertilizer applicator during operation [2]. Uniformity allows for better distribution of the fertilizer in the root zone and better nutrient utilization efficiency [12]. In some developing countries, farmers have been noted to apply fertilizers to their cropland without measurements leading to excessive and indiscriminate applications [6].

This has continued because of a lack of adequate tools, training and much needed innovations, this, in turn, leads to the over-fertilization and, in some cases is responsible for the increased soil acidity. Overfertilization occurs when an excessive amount of nutrients, such as nitrogen, phosphorus, and potassium, is applied to soils [5]. While nutrients are essential for plant growth, exceeding the optimum levels can lead to a multitude of problems [7].

Excessive fertilizer applications have also been noted to cause physical, chemical, and biological damage to the soil and decrease the soil fertility [4]. Selecting fertilizer materials and then matching fertilizer application rates to crop needs is essential for optimal crop production [13]. However different crops in different fields require varying amounts of fertilizer materials due to variation in soil types, soil fertility levels, and nutrient needs [14].

Farmers commonly apply side-dressing or top-dressing fertilizers on growing row crops using hand measurements, often with improvised tools such as a cup. This study aimed to develop, fabricate, and test a hand-held, low-cost manual fertilizer applicator (MFA) made from polyvinyl chloride (PVC) to accurately place granular urea at the required soil depth and distance from plants, minimizing exposure to the environment during application. The MFA was designed as a technically simple, easy-to-operate device capable of efficiently applying a predetermined quantity of fertilizer using locally available materials.

The design of the applicator also considers ergonomics to ensure comfort and ease of use, particularly for youth, women, and adult smallholder farmers, who are the primary potential end users. Fertilizers are applied close to the seed or plant to supply nutrients in adequate amounts to the roots of growing crops [15]. To address the limitations of conventional side-dressing and top-dressing methods, a manually operated granular fertilizer applicator was developed. The performance of the implement was evaluated in terms of ease of operation, field efficiency, and affordability.

2. Materials and Methods

The Raw Materials used for manufacture of prototype technology were

Table 1. Row material.

NO	Component	Specification
1	PVC Pipe,	¾ and ½ diameter
2	Handle bar	Steel Water pipe ¾
3	Hopper	Plastic jerrican (oil jar)
4	Flexible hose	¾ diameter plastic tube

2.1. Machine Description

The fertilizer applicator has an overall height of 1.50m and a total weight of 2.2kg. A hole was drilled at the bottom of the hopper to allow discharge of its contents. The quantity of fertilizer flowing from the hopper to the metering unit was controlled manually using a hand press, while the application rate was regulated by adjusting the diameter of the discharge pipe.

2.2. Hopper

The hopper has a capacity of 18.4m^3 and is constructed from a rectangular jerrican to store the fertilizer. A hole was drilled at the bottom to allow discharge of its contents. The hopper is connected to the applicator assembly using a flexible plastic connector, which conveys the fertilizer to the flexible pipe. The hopper material was chosen to ensure smooth flow of fertilizer, preventing the formation of pockets along the edges of the tank.

Figure 1. Hopper and whole part.

2.3. Fertilizers Tube Pipe

The fertilizer tube was made of PVC pipe and featured two holes of equal diameter. One end was fitted with a reducing socket, while the other end was connected to the flexible discharge pipe. Fertilizer from the storage tank flowed through the flexible pipe into the fertilizer tube for application.

2.4. Test Conditions

Performance of the implement varies with the type of the hole diameter, and operator. The test plot was 27.5m X 20 m, three replication for each treatment.

3. Performance Evaluation Procedure

The parameters are field capacity, field efficiency and application rate were taken as performance indicator. The implement was evaluated for field capacity, field efficiency and uniformity of fertilizer deliver to crops correct amount at proper location. The performance of the manual applicator was evaluated by estimating the fertilizer delivery rate and the land area covered per unit volume of loaded fertilizer. The application rate was determined by measuring the quantity of fertilizer delivered in kilograms per hectare. All measurements were conducted in replicates to ensure accuracy and reliability. The estimated number of applications from a fully loaded manual fertilizer applicator was determined based on the calculated area of land to be covered.

Application rate

The application rate, defined as the amount of fertilizer applied per unit area, was calculated using the following equation:

$$Q = \frac{M}{A}$$

Where; Q = Application rate
M = mass of fertilizer (kg)
A = area covered (ha)

Effective field capacity (ha/hr.)

The effective field capacity, defined as the actual area covered per unit time, was determined using the following equation.

$$Efc = \frac{A}{t}$$

Where A=is the area covered, m2
t =is the time used during the operation, hr.

Labor required

Single man/woman can operate the implement without any drudgery involvement and it takes less time to cover the farm land as per the required application rates.

Figure 2. *Picture taken during operation the developed machine and traditional.*

4. Result and Discussion

As observed from Table 2, there was a mean difference in the application rate of fertilizer between male and female operators. The main effect of hole diameter was found to be highly significant ($p < 0.001$) on the fertilizer application rate, indicating that the size of the discharge hole had a strong influence on the amount of fertilizer applied. However, the interaction effect between gender and hole diameter was not statistically significant.

Table 2. Analysis of Variance (ANOVA) for Application Rate.

	Df	Sum Sq	Mean Sq	F value	Pr (>F)
Gender	1	5642	5642	4.298	0.0443*
Hole diameter	2	109535	54767	41.716	1.05e-10***
Interaction	2	388	194	0.148	0.8632
Residuals	42	55140	1313		

Table 3. The main effect of gender and hole diameter for application rate and field capacity for tomato and red paper.

Tomato			**Red paper**	
Gender	**Application rate (kg/ha)**	**Field capacity (ha/hr)**	**Application Rate (kg/ha)**	**Field capacity (ha/hr)**
Male	251.3[a]	1.19[a]	252.42[a]	1.19a
Female	229.6[b]	1.03[b]	233.71[b]	1.03b
LSD	21.11	0.07	15.75	0.07
Hole diameter (cm)	Application rate (kg/ha)	Field capacity (ha/hr)	Application rate (kg/ha)	Field capacity (ha/hr)
3	187.4[a]	0.87[a]	185.00[a]	0.87[a]
4	230.6[b]	1.04[b]	239.20[b]	1.04[b]
5	303.2[c]	1.42[c]	305.00[c]	1.42[c]
LSD	25.85	0.09	19.29	0.09
CV%	15.1	11.0	11.1	10.0

From Table 3 it noted that the effect of the gender and hole diameter on field capacity shows significance difference for each means.

Table 4 shows that the maximum application rate of 311.96 kg/ha and 1.55 ha/hr. of field capacity was recorded when operated by men at 5 cm and also the minimum and maximum application rate and maximum field capacity of 178.53, 294. 46 kg/ha and 1.29 ha/hr. when operated by women at 3 and 5 cm respectively tomato.

Table 4. combination effect of hole diameter and gender application rate of Tomato and red paper.

Tomato							**Red paper**					
Gender	**Application rate (kg/ha)**			**Field capacity (ha/hr)**			**Application rate (kg/ha)**			**Field capacity (ha/hr)**		
	3cm	**4cm**	**5cm**	**3cm**	**4cm**	**5cm**	**3cm**	**4cm**	**5cm**	**3cm**	**4cm**	**5cm**
Male	196.4	245.5	311.96	0.9	1.2	1.6	191.8	250.0	315.5	0.9	1.1	1.5
Female	178.5	215.73	294.46	0.85	0.94	1.29	178.18	228.41	294.55	0.84	0.95	1.34
Grand mean	240.4			1.11			243.07			1.11		
LSD	36.56			0.123			27.28			0.11		

5. Conclusions and Recommendations

5.1. Conclusion

Based on performance indicator taken to evaluate the treatments it can be concluded that:-The technology was save time with 5 diameter size but it cause out of recommendation applied per hectare, The 3 diameter hole was saves fertilizer and shows advantage over the both diameter in low application rate Even though the field capacity was highest recorded at 5 diameter and spend a list time to cover a given area, it cause excessive fertilize was applied to the farm land according to (Kahsay, Embaye, and Tekle 2016) 150 kg/ha to 200 kg/ha for tomato. The reduction in drudgery and improvement in operational efficiency were evident during field evaluations. Traditionally, fertilizer side-dressing operations, particularly for maize and vegetable crops, require intensive manual labor and are physically demanding. However, farmers' feedback and field observations indicated that the improved manual fertilizer applicator significantly reduced operator fatigue and labor intensity. The applicator was found to be comfortable and easier to use compared to the conventional hand-application method, which farmers described as strenuous and time-consuming.

5.2. Recommendation

Generally, As the implement was very simple and can produced from locally available materials it can be multiply and distribute this technology to farmer, simple and easy to operate the implement was low cost and affordable to small scale farmers.

Abbreviations

PVC	Polyvinyl Chloride
MFA	Manual Fertilizer Applicator

Author Contributions

Mateos Belina: Conceptualization, Data curation, Formal Analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing

Merga Warqesa: Data curation, Validation, Visualization, Writing – original draft, Writing – review & editing

Abdurehaman Sultan: Validation, Visualization, Writing – original draft, Writing – review & editing

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

Appendix

Authorship Agreement Form

To reduce authorship/order disputes among researchers, all authors need to sign an authorship agreement form that is verified by the process owner, center director, and research director. Authorship order ensures the right people get the cred it and take responsibility for the research. Authors need to fulfill the criteria set in the IQQO Proceeding Publishing Guideline.

Date: 08/05/2016

Research Team: AMFPE

Research Center: Bako Agricultural Engineering Research Center

We hereby affirm that authorship lists/orders provided for each manuscript in this form are accurate and according to IQQO Proceeding Publishing Guideline.

S. No	Research Title	Authorship Order
1	Adaptation and Performance Evaluation of Manual Operated Fertilizer Applicator	1st: Mateos Belina 2nd: Merga Warqesa 3rd: Abdurehaman Sultan

*A hard copy of the agreement will be documented at a center level for at least five years, and a scanned document will be submitted to the respective Research Director with the

References

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