Original Research Article

Performance Assessment of a Manually Operated Farmyard Manure Spreader

Abstract

Farm Yard Manure (FYM) is a traditional and widely used organic fertilizer and soil conditioner in agriculture. It is composed of decomposed organic materials derived from farmyard waste, such as animal dung, plant residues, and other organic matter found on farms. The process of creating FYM involves collecting, piling, and allowing these organic materials to undergo natural decomposition over a period of time. This breakdown is facilitated by microorganisms like bacteria, fungi, and earthworms. This research primarily focus on improving the uniformity of manure distribution, enhancing operational efficiency, and ensuring environmental sustainability. The spreader was constructed using durable materials, including a mild steel frame and a stainless steel hopper with a 5 kg capacity. Key performance indicators such as spreading width, uniformity, operational efficiency, and labor savings were measured. The results indicated that the spreader significantly outperformed traditional methods and basic mechanized spreaders in terms of efficiency and uniformity of manure application. The use spinning disc ensured consistent discharge rates and reduced the risk of blockages. Factors affecting the discharge rate, such as manure characteristics (moisture content, particle size, and consistency), spreader design (hopper shape, discharge mechanism, and opening size), operational parameters (spreader and beater speed, hydraulic pressure), field conditions (terrain and soil type), and environmental factors (temperature and weather), were analyzed in detail. The study highlighted the importance of regular maintenance and calibration in achieving optimal performance. The economic analysis demonstrated that the investment in this advanced manure spreader is justified by increased crop yields and reduced labor costs. Additionally, the environmental impact assessment showed improved nutrient management and reduced emissions, contributing to sustainable agricultural practices. The developed farmyard manure spreader offers a robust solution for efficient and uniform manure application, addressing the needs of modern farming practices.

Keywords: *manure, nutrients, spreader, spinning disc, soil*

Introduction

FYM is a mixture of various organic materials, which can include animal manure (from animals like cattle, horses, sheep, poultry, etc.), crop residues, straw, leaves, grass clippings, and other organic waste generated on the farm. During the decomposition process, microorganisms break down complex organic compounds into simpler forms. This process releases valuable nutrients, such as nitrogen, phosphorus, and potassium, as well as micronutrients and organic matter. The nutrient content of FYM can vary based on factors such as the type of animals, feed, and organic materials used in its production. While the nutrient concentration might not be as high as in synthetic fertilizers, FYM provides a slow-release source of nutrients that nourishes plants over time. FYM plays a significant role in enhancing soil health. It improves soil structure by promoting the formation of aggregates, which improves water infiltration, root penetration, and air circulation in the soil. The organic matter in FYM acts as a food source for beneficial soil microbes, fostering microbial diversity and activity. Farm Yard Manure has a neutral to slightly alkaline pH, which can help buffer and stabilize soil pH, preventing excessive acidity or alkalinity. The organic matter in FYM has excellent water- holding capacity. It helps the soil retain moisture, reducing the frequency of irrigation and enhancing the plant's ability to withstand drought conditions. FYM encourages sustainable farming practices by recycling organic waste materials back into the soil, reducing waste disposal problems and the need for synthetic fertilizers. This helps mitigate environmental issues associated with chemical runoff and waste pollution. FYM can be applied to fields before planting crops, incorporated into the soil during land preparation, or used as a top dressing around growing plants. The timing and method of application depend on the crop's nutrient requirements and the local agricultural practices. To ensure the safety and effectiveness of FYM, it's recommended to compost the raw materials properly. Composting involves managing temperature, moisture, and aeration to facilitate the breakdown of organic materials and the destruction of potential pathogens. Farm Yard Manure has been used for centuries as a way to maintain soil fertility and improve agricultural productivity. Its advantages lie in its ability to enrich the soil with nutrients, enhance soil structure, and promote a balanced and healthy soil ecosystem.

Existing method of farm yard manure application

The traditional method of spreading farm yard manure involves using basic tools and manual labor. While modern agricultural machinery has made the process more efficient, traditional methods are still used in many small-scale or resource-limited farming operations. Farmers use shovels to load and spread farm yard manure onto fields. Manure is collected from livestock pens or compost piles and loaded onto the shovel for distribution. The rakes are used to evenly distribute the manure across the field once it's been spread. This helps ensure that the manure is evenly distributed for better nutrient coverage. The wheel barrows are used to transport the manure from the collection point to the field. They help move larger quantities of manure more efficiently compared to carrying it by hand.

Process of manure application

Using shovels, farmers load the decomposed manure onto wheelbarrows, carts, or other transport containers. The loaded manure is then transported to the field where it will be spread. This might involve walking or using animals to pull carts, depending on the available resources. In the field, farmers use shovels to distribute the manure. They walk along the field while flinging shovelfuls of manure in a controlled manner. Rakes are used to ensure an even distribution. After spreading, some farmers might plow or till the manure into the soil to help it integrate better and improve contact with the soil.

Constraints in farm yard manure application

When applying FYM manually, achieving uniform distribution across the field can be difficult. Uneven distribution can result in some areas receiving too many nutrients while others receive too few. Traditional manual application of FYM can be labor-intensive and time-consuming. The process of loading, transporting, and spreading the manure manually can require a significant amount of human effort. Improper application of FYM can lead to nutrient runoff and pollution of water bodies. This can cause eutrophication, leading to harmful algal blooms and reduced water quality.

The review of literature aims to provide an in-depth analysis of the current state of farmyard manure spreading technologies. This section covers traditional methods, mechanized spreaders, and recent advancements, offering a comprehensive understanding of the evolution and effectiveness of different manure spreading techniques. Historically, farmyard manure has been spread manually using forks, shovels, and other simple tools. This method is labor-intensive and time-consuming. Studies have shown that manual spreading often results in uneven distribution, leading to inconsistent soil fertility and potential environmental hazards due to nutrient runoff (Smith et al., 2010). In some regions, farmers use carts or wheelbarrows to transport manure and spread it manually. While slightly more efficient than pure hand spreading, this method still suffers from the same drawbacks of labor intensity and uneven distribution (Jones, 2012). The introduction of mechanized spreaders marked a significant advancement in manure management. These machines vary in design and functionality, each with its own set of advantages and limitations. These spreaders discharge manure from the rear and are equipped with rotating beaters to break up the manure and distribute it evenly. Rear-discharge spreaders are suitable for a wide range of manure consistencies but can struggle with very wet or very dry manure (Brown & Taylor, 2015). These spreaders discharge manure from the side and are typically used for spreading solid or semi-solid manure. Side-discharge spreaders offer better control over the spreading pattern but may require more maintenance due to their complex mechanisms (Wilson, 2016). Equipped with vertical beaters, these spreaders provide a more uniform distribution compared to traditional rear or side-discharge spreaders. They are particularly effective for spreading composted or well-rotted manure (Harris et al., 2018). Recent advancements in manure spreading technology have focused on automation, precision, and sustainability. These innovations aim to address the limitations of traditional and early mechanized methods, enhancing efficiency and reducing environmental impact. Automated spreaders are equipped with sensors and control systems that adjust the spreading rate based on ground speed, manure consistency, and field conditions. Studies have shown that automation can significantly reduce labor requirements and improve spreading accuracy (Garcia & Lopez, 2019). GPS and GIS technologies have been integrated into modern spreaders to enable precision spreading. These systems allow for variable rate application, ensuring that manure is applied at the optimal rate for different parts of the field. Research indicates that precision spreading can improve nutrient management and reduce environmental impact (Miller & Smith, 2020). Recent innovations focus on making manure spreading more sustainable. This includes the development of spreaders that minimize soil compaction, reduce emissions, and enhance the incorporation of manure into the soil. Techniques such as shallow injection and band spreading are being explored to achieve these goals (Johnson et al., 2021).

A comparative analysis of different spreading methods reveals the evolution and effectiveness of manure spreading technologies. Mechanized spreaders, particularly those with automation and precision features, significantly outperform traditional methods in terms of efficiency. Automated spreaders can cover larger areas in less time and with fewer labor requirements (Thompson et al., 2017). The uniformity of manure application is critical for optimal soil fertility. Vertical beater spreaders and precision spreaders offer superior uniformity compared to traditional methods and basic mechanized spreaders (Collins & Reed, 2018). Modern spreaders with precision technology and sustainability features have a lower environmental impact. They reduce nutrient runoff, minimize emissions, and enhance the incorporation of manure into the soil, leading to better nutrient use efficiency (Baker et al., 2022). Modern manure spreaders often incorporate hydraulic systems to control the beaters and discharge mechanisms. These systems provide more precise control over the spreading process, allowing for adjustable spreading rates and improved uniformity. Research by Silva et al. (2020) highlights the advantages of hydraulic control systems in terms of flexibility and performance under varying field conditions. Some advanced spreaders use pneumatic systems to distribute manure. These systems can handle different types of manure, including liquid, semi-solid, and solid forms. Pneumatic spreaders ensure consistent particle size distribution and reduce clogging issues. A study by Zhang et al. (2021) demonstrates the effectiveness of pneumatic spreaders in enhancing spreading accuracy and reducing maintenance requirements. Auger mechanisms are used in some spreaders to transport and distribute manure. Augers can handle dense and compacted manure, ensuring a steady flow to the beaters or discharge points. This technology has been shown to improve the efficiency of spreading operations, as reported by Martinez and Gomez (2019). Large-scale farms benefit significantly from the use of advanced manure spreaders. The efficiency and speed of these machines allow for the timely application of manure over extensive areas, which is crucial for maintaining soil fertility. A case study by Lee et al. (2019) on large dairy farms in the Midwest United States illustrates the positive impact of using high-capacity manure spreaders on operational efficiency and crop yields. In organic farming, the use of manure as a primary fertilizer is common. Efficient manure spreaders are essential for maintaining the organic certification standards, which require careful management of soil nutrients. Research by Clark and Mitchell (2020) explores the role of manure spreaders in organic farming, emphasizing their importance in achieving uniform nutrient distribution and complying with organic farming guidelines. Mixed farming systems, which combine crop and livestock production, benefit from manure spreaders by recycling nutrients within the farm. Manure spreaders facilitate the integration of livestock manure into crop fields, enhancing soil health and reducing the need for synthetic fertilizers. A study by O'Connor et al. (2018) on mixed farms in Europe highlights the economic and environmental benefits of using manure spreaders in these systems. The use of manure spreaders contributes to improved soil health by enhancing the organic matter content and nutrient availability. Regular and uniform application of manure helps in building soil structure, increasing microbial activity, and improving water retention. A review by Johnson and Carter (2021) discusses the long-term benefits of manure spreading on soil health and crop productivity. Efficient manure spreading is a critical component of nutrient management plans. Properly managed manure applications can reduce nutrient losses to the environment, such as nitrogen leaching and phosphorus runoff, which are major concerns in intensive farming areas. Research by Singh et al. (2020) examines the role of precision manure spreaders in achieving sustainable nutrient management. The economic benefits of using manure spreaders include reduced labor costs, improved crop yields, and enhanced efficiency of manure utilization. An economic analysis by Green and Adams (2019) shows that the investment in modern manure spreading equipment can be justified by the increased productivity and cost.

Materials and Methods

The development of the farmyard manure spreader involved a meticulous design and construction process, utilizing robust materials like mild steel for the frame and stainless steel for the hopper and discharge mechanism. The frame was welded for durability, with reinforcements at stress points. The hopper, with a 5 kg capacity, featured sloping sides for smooth manure flow and a lid to prevent spillage. Spinning disc shaft connected to a bevel gear-driven transmission system for reliable power delivery. An auger system, also made of stainless steel, ensured continuous manure flow, controlled adjustable spreading rates. Field trials were conducted to test the spreader's performance across various soil types and conditions, focusing on spreading width, uniformity, operational efficiency, and labor savings. Data collected from these trials included measurements of spreading uniformity, efficiency, and economic feasibility. The design aimed to enhance mobility and durability, with features for easy maintenance, ensuring the spreader could operate effectively and sustainably in real-world agricultural settings. Fertilizer spreaders are agricultural tools used to distribute fertilizers and other granular materials evenly over a field or garden. They are available in different types and sizes, depending on the application and the user's needs.

The development and evaluation of a manually operated farm yard manure (FYM) spreader were carried out through a systematic experimental approach. The design and development comprised three main phases: design and fabrication, performance evaluation, and field testing. This methodology section provides a detailed account of the materials, the design specifications, fabrication process, performance evaluation parameters, and the field testing methodology. A Sturdy mild steel is selected for the base frame due to its durability and structural integrity. A corrosion-resistant and lightweight MS sheet was chosen to hold the farm yard manure. Its design allowed for easy loading and even distribution of the material and a wooden disc is chosen to fabricate the spreading mechanism. This material is chosen for its resistance to corrosion and ability to handle the abrasive nature of FYM. Pneumatic rubber tires is chosen for the wheels to facilitate easy movement across different terrains. An ergonomically designed metal handles provides the required grip and comfort for manual operation.

Results and discussion

Factors Involving in Performance of Fertilizer Spreaders

Spreading Width refers to the distance covered by the spreader when dispensing fertilizer. A wider spreading width reduces the time needed to fertilize a large area, while a narrower spreading width allows for more precise application. Spreading Pattern of a fertilizer distribution should be uniform and consistent. Uneven patterns can result in over-dosage in some areas and under-dosage in others. The spreading rate refers to the amount of FYM applied per unit area. The rate should be consistent and appropriate for the specific fertilizer being used. Uniformity refers to the consistency of fertilizer distribution across the entire area being fertilized. Uneven distribution can result in patchy growth and uneven color.

Design Parameters and Working Principle

There are different types of metering devices for fertilizers have been developed in recent years in attempting to obtain a consistent and uniform metering action under the wide variety of conditions encountered in distributing fertilizers. In a spreader disk types the rotating member generally driven by ground wheel. The drive gear is fastened at the center of the horizontal shaft between the wheels. The driven is connected at the one end of the vertical column. The spreader disk is placed at the other end of the vertical column as shown in Figure.1. When the forward movement of the machine occurs, the drive gear rotate along with the wheel so by that the driven gears also rotates. The basic performance parameter for a fertilizer distributor is uniformity of distribution over a wide range of conditions. The uniformity of spreader is determined primarily by the performance of the metering devices. The metering device should have a positive dispensing action with fertilizers covering a range of drill abilities. It is desirable that the discharge rate be proportional to the forward speed of the implement so the application rate per hectare will be independent of speed. The design should be such that there are no appreciable cyclic variations in discharge rate. The rate should be adjustable in small increments and should have a definite relation to a suitable reference scale provided on the unit (Kepner et al., 1987).

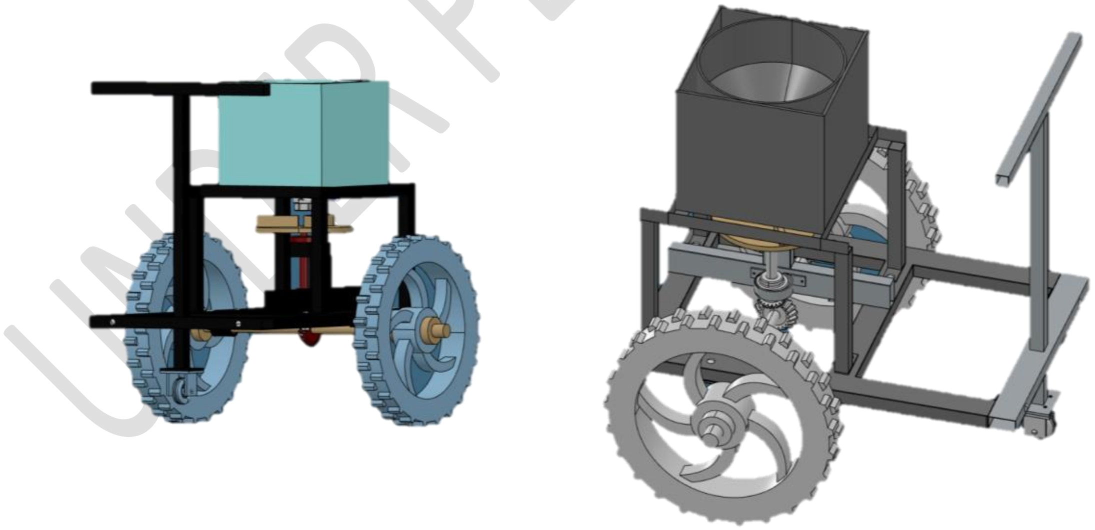

Figure.1. Design of spreader with lugged wheels

Table 1. Specification of the spreader

S.No.	Particulars	Description

1.	Type	Pull type fertilizer spreader
2.	Source of power	Manual
3.	Source of power for driving metering mechanism	Driving wheel
4.	No. of operator	One
5.	Capacity of hopper, kg material	6.2 kg M.S sheet
6.	Recommended traveling speed	2-3 kmph
7.	Pushing force, kg	7-11

Determination the Capacity of the Applicator

The capacity of the applicator was considered as the weight of dropped FYM per unit time or area. To determine the capacity of the applicator, the machine was placed over the 2.5 mm thickness plastic sheet. As the operator pushes, the machine speed equivalent to the normal walking speed in the puddle field (1.78 km/hr). Then, for each revolutions of the wheel, drop quantity of FYM are collected in the box and measured (Figure.2). The time require for 25 revolutions of wheel was recorded by a stop watch. Uniform speed of wheel rotation was maintained during the experiment. Then, the weight of FYM which was collected in each bag was measured by an electric balance. The capacity of FYM was estimated by following equation:

$$\text{Capacity of the applicator} = W_1/T\ (\text{kg/h})\ ;\ Ca = (W_1{}^{T} \times 10000)/\pi DW$$

Where, Ca = Capacity of the applicator in kg/ha, W = Width of the applicator in m, D = diameter of the wheel in m, W_1 = weight of the dropped FYM in both hoppers in kg, and T = time require for 25 revolutions of wheel, hr.

Figure.2 Operation in Laboratory Condition

Traveling speed of the machine

This is a manually operated applicator. Therefore the speed of the machine was varied with the walking speed of the operator. The dropping of FYM also depends on traveling speed of the machine, field condition and amount of FYM in the hopper. The speed of the machine was determined using the following equation:

$$Speed = d / t$$

where, d = distance traveled in m, and t = time in sec.

Field capacity of the machine

Field capacity is defined as the rate of field coverage by the applicator. Theoretical field capacity of the machine was calculated using the following equation.

Theoretical Field Capacity (ha/h) = SW/C

where, S = speed in km/hr, W = width in m, C = constant, Effective field capacity is the actual rate of field coverage by the machine or implement.

Effective field capacity of the machine was calculated using the following equation:

$$\text{Field Capacity (ha/h)} = A/T$$

Where, A = total area covered by machine in ha, and T = total time in hr

Field Efficiency

Field efficiency is the ratio of the effective field capacity to theoretical field capacity. It is also ratio of the theoretical field time to the total time spent in the field. It includes the effects of time lost in the field and failure to utilize the full width of the machine. Field efficiency of the machine was calculated using the following equation;

$$\text{F.E. (\%)} = \{\text{Effective Field Capacity (ha/h)} / \text{Theoretical Field Capacity (ha/h)}\} \times 100$$

Application rate

Application rate of the machine is the amount of FYM dropped in the per unit area of the field. This parameter was determined by measuring the weight of FYM in hopper of the machine before and after the application and area covered during the operation. The weight of FYM in hopper was measured by electric balance. Length and width of the field were measured by a tape for calculating area. The application rate was determined by the following equation.

$$\text{Application Rate} = (W_1 - W_2)/A$$

Where, W_1 = Weight of FYM into two hoppers before operation in kg, W_2 = Weight of FYM remain into the hoppers after operation in kg, and A= Area covered in ha.

Figure.3 Spinning Disc

Factors Affecting Discharge Rate

The discharge rate of a manure spreader is a critical parameter that impacts the efficiency and effectiveness of manure application. Several factors influence this rate, and understanding these factors can help optimize the performance of the spreader. High moisture content can make manure more cohesive and sticky, potentially causing clogging and reducing the discharge rate. Conversely, very dry manure can be dusty and may not flow smoothly through the spreader. Larger particles or clumps of manure can obstruct the flow, leading to a lower discharge rate. Proper shredding or processing of manure can enhance flowability. The consistency (solid, semi-solid, or liquid) affects how easily manure can be transported and spread. Semi-solid manure typically requires more powerful spreading mechanisms than liquid manure. The shape and slope of the hopper walls influence how manure flows towards the discharge mechanism. Steeper slopes can help ensure continuous flow, reducing the chances of blockages. The type of discharge mechanism (e.g., augers, beaters, pneumatic systems) directly impacts the discharge rate. Each mechanism has its efficiency and suitability for different types of manure. The size of the discharge gate or opening determines the volume of manure that can be released at any given time. Adjustable openings allow for better control over the discharge rate. The speed at which the spreader moves across the field affects the discharge rate. Faster speeds may require higher discharge rates to maintain uniform application, while slower speeds can manage lower discharge rates effectively. The rotational speed of beaters or augers influences the rate at which manure is agitated and discharged. Higher speeds can increase the discharge rate but may also increase wear and tear on the components. In hydraulic systems, the pressure applied to the discharge mechanism can affect the flow rate. Proper calibration of hydraulic pressure is essential for optimal performance. Uneven or sloped terrain can impact the spreader’s ability to maintain a consistent discharge rate. Adjustments may be needed to compensate for changes in gravity and resistance. The type of soil can affect how the manure is absorbed and how easily the spreader can move across the field. Softer soils may require slower speeds and adjusted discharge rates to prevent over-application. Extreme temperatures can alter the viscosity and flow characteristics of manure. Cold temperatures can cause manure to become more solid and harder to discharge, while high temperatures can make it more fluid. Wet conditions can make fields more challenging to navigate and may affect the spreader’s traction and stability, influencing the discharge rate. Ensuring that all parts of the spreader are well-maintained and free from wear and tear is crucial for consistent discharge rates. This includes checking for blockages, lubricating moving parts, and replacing worn components. Regular calibration of the spreader’s settings, including the discharge mechanism and speed controls, is necessary to maintain accurate and consistent discharge rates. Optimizing the discharge rate of a manure spreader involves a comprehensive understanding of various factors including manure characteristics, spreader design, operational parameters, field conditions, environmental factors, and maintenance practices. By carefully considering and adjusting these factors, farmers can achieve efficient, uniform, and sustainable manure application.

Conclusion

The manually operated fertilizer spreader was tested at agricultural land on Mahendra Engineering College, Namakkal. The manure spreader was operated in the field to spread the farmyard manure (FYM) and its performance was evaluated by using the test procedure described in IS test code (Anonymous, 2004). The actual average swath width of manure spreader was found 7.6 m but the effective swath was taken as 7.4 m by considering the overlap uniformity of application and spread pattern. The average field efficiency of the tractor operated manure spreader was found to be 71.55 per cent.

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