

**PERFORMANCE EVALUATION OF
FARMYARD MANURE PULVERIZER CUM
SPREADER**

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B. Tech. (Agril. Engg)

**MASTER OF TECHNOLOGY
IN
AGRICULTURAL ENGINEERING
(FARM MACHINERY AND POWER)**



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BY

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Thesis submitted to the
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CHAIRPERSON: Dr. S. JOSEPH REDDY



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2015**

DECLARATION

I, **NKR GURUDATT MADDU**, hereby declare that the thesis entitled “**PERFORMANCE EVALUATION OF FARMYARD MANURE PULVERIZER CUM SPREADER**” submitted to the **Acharya N. G. Ranga Agricultural University** for the degree of **Master of Technology in Agricultural Engineering** is the result of original research work done by me. I also declare that no material contained in the thesis has been published earlier in any manner.

Place: Bapatla

Date: 18-6-2015

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I.D. No. BEM 13-002

CERTIFICATE

Mr./Ms. **NKR GURUDATT MADDU** has satisfactorily prosecuted the course of research and that thesis entitled “**PERFORMANCE EVALUATION OF FARMYARD MANURE PULVERIZER CUM SPREADER**” submitted is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination. I also certify that, neither the thesis nor its thereof has been previously submitted by him/her for a degree of any University.

Date: 18-6-2015

Chairperson

CERTIFICATE

This is to certify that the thesis entitled “**PERFORMANCE EVALUATION OF FARMYARD MANURE PULVERIZER CUM SPREADER**” submitted in partial fulfilment of the requirements for the degree of **MASTER OF TECHNOLOGY** in **AGRICULTURAL ENGINEERING** in (**FARM MACHINERY AND POWER**) to the Acharya N. G. Ranga Agricultural University, Bapatla is a record of the bonafide original research work carried out by Mr. /Ms. **NKR GURUDATT MADDU** under our guidance and supervision.

No part of the thesis has been submitted by the student for any other degree or diploma. The published part and all assistance received during the course of the investigations have been duly acknowledged by the author of the thesis.

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Place:

Date:

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ABSTRACT

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On one side of the coin negative impacts coupled with escalating prices of mineral fertilizers and on other side high demands of nutrients to soil due to intense cultivars of high yielding varieties, the use of organic matter is necessary to meet the nutrient demands with low cost. In India application of farmyard manure (FYM) to the agricultural fields has been generally accepted practice, which improves soil physical, chemical and biological properties of soil. Keeping in view the problems of not meeting the desired agronomic rates and disintegration of large manure un-decomposed clods during manual application of FYM to the field, a machine (FYM pulverizer cum spreader) was developed by RARS, Nandyal to pulverize and spread the manure simultaneously to the fields. Pulverization of large un-decomposed FYM clods to 0 to 40 mm size encourages the faster decomposition when hits the lands due to the more surface area exposed for the attack of microorganisms present in the soil, environment and FYM.

To meet the desired FYM application rates to the fields in required pulverized form, it is necessary to study the physical properties of manure affecting the performance of the machine and behavior of the machine at different component settings and operated under prescribed levels. Hence, a study was carried out on the performance evaluation of the FYM pulverizer cum spreader. The machine parameters with levels viz., feed control shutter opening (half open and full open), number of blades per flange of rotor (2, 3, and 6) and operational parameters viz., spreader peripheral velocity (4.72 ms^{-1} , 6.92 ms^{-1} and 7.86 ms^{-1}) spreader forward speed of (2 Km h^{-1} , 3 Km h^{-1} and 5 Km h^{-1}) were selected to study the effect on bulk density, clod size distribution and FYM application rate. Based on the study, the machine and operational parameters were optimized for minimum bulk density, higher percentage of 0 to 40 mm clod distribution and desired range of agronomic application rates.

The experiments were carried out at stationary condition as well as in field conditions. The experiments revealed that, the decrease in bulk density and increase in percentage of 0 to 40 mm clod size distribution was observed when the rotor peripheral velocity was increased from 4.72 ms⁻¹ to 7.86 ms⁻¹ and numbers of blades were increased from 2 to 6. The lowest bulk densities of 0.510 g cm⁻³ and 0.515 g cm⁻³ and higher 0 to 40 mm clod size percentages of 78.28 and 66.55 was recorded at peripheral velocity of 7.86 ms⁻¹ and 3 number of blades for both half and full shutter opening of the machine respectively. The application rate was increased when rotor peripheral velocity increased and decreased with increase in forward speed. The agronomic application rates of 5.8 t ha⁻¹ and 12.6 t ha⁻¹ with minimum bulk density and higher percentage of 0 to 40 mm clod size distribution was observed at forward speed of 3 Km h⁻¹, peripheral velocity of 7.86 ms⁻¹ and 3 blades per flange of rotor at half shutter and full shutter opening.

A prototype FYM pulverizer cum spreader was developed and evaluated under field condition with the best optimized variables derived from the experimental trails. The bulk density, clod size distribution and application rate was observed as 0.512 g cm⁻³ & 0.521 g cm⁻³, 75.99 % & 64.45 % and 5.9 t ha⁻¹ & 12.5 t ha⁻¹ at half and full shutter opening area respectively. The cost of operation of FYM pulverizer cum spreader works out to be Rs.620 per acre when the machine is used for dry FYM pulverizing cum spreading operation. There was a saving of Rs.504 per acre over traditional method of spreading.

APPENDIX I

Cost of Operation of FYM Pulverizer cum Spreader

	Tractor	FYM pulverizer cum spreader
Purchase value (C), Rs	740000	260000
Salvage value (S), Rs	74000	26000
Life (yrs)	10	8
Annual working hours (H)	1000	600
Interest (i), %	12	12
Annual insurance charges (I), Rs	9000	-
Annual tax charges (T), Rs	5000	1200
Annual shelter charges (S), Rs	12000	6000
Tractor rated power (kW)	36.7	-
Fuel cost (Rs lit ⁻¹)	55	-
Lubrication oil cost (Rs lit ⁻¹)	270	-
Labor required (No`s)	1 (driver)	1 (helper)
Annual labor charges (Rs)	72000	43200

I. Cost of Operation of Tractor

Tractor	Calculation	Cost (Rs.)
1. Depreciation per hour = $\frac{(C - S)}{LH}$	$= \frac{(740000 - 74000)}{10 \times 1000}$	= 66.6
2. Interest rate per hour = $\frac{(C + S)}{2} \times \frac{i}{H}$	$= \frac{(740000 + 74000)}{2} \times \frac{12}{100 \times 1000}$	= 48.4
3. Cost of housing per hour = $\frac{S}{H}$	$= \frac{12000}{10 \times 1000}$	= 12.0
4. Insurance per hour = $\frac{I}{H}$	$= \frac{9000}{10 \times 1000}$	= 9.0
5. Tax per hour = $\frac{T}{H}$	$= \frac{5000}{10 \times 1000}$	= 5.0
A. Fixed cost per hour = (1) + (2) + (3) + (4) + (5)		= 141.44
6. Fuel consumption $\left(\frac{\text{lit}}{\text{h}}\right)$ = 15% × Tractor rated power (kW)	$= \left(\frac{15}{100}\right) \times (36.7)$	= 5.50
7. Fuel cost per hour = Fuel consumption $\left(\frac{\text{lit}}{\text{h}}\right) \times$ cost of fuel $\left(\frac{\text{Rs}}{\text{lit}}\right)$	$= 5.505 \times 55$	= 302.55
8. Lubrication oil consumption cost per hour $\left(\frac{\text{lit}}{\text{h}}\right)$ = 3% × Fuel consumption $\left(\frac{\text{lit}}{\text{h}}\right)$	$= \frac{3}{100} \times 5.505$	= 0.16
9. Lubrication oil consumption cost per hour = Lubrication oil consumption cost per hour $\left(\frac{\text{lit}}{\text{h}}\right)$ × cost of fuel $\left(\frac{\text{Rs}}{\text{lit}}\right)$	$= 0.1615 \times 5.505$	= 44.59
10. Repair cost per hour = $2\% \times \frac{C}{H}$	$= \frac{2}{100} \times \frac{740000}{10 \times 1000}$	= 1.48
11. Driver cost per hour = $\frac{\text{Driver salary per year}}{H}$	$= \frac{7200}{1000}$	= 72.0
B. Variable cost per hour = 7 + 9 + 10 + 11		= 420.62
I. Cost of operation of tractor per hour = fixed cost per hour (A) + variable cost per hour (B)	$= 141.44 + 420.62$	= 562.06

II. Cost of Operation of FYM Pulverizer cum Spreader

FYM Pulverizer cum spreader machine	Calculation	Cost (Rs.)
1. Depreciation per hour = $\frac{(C - S)}{LH}$	$= \frac{(260000 - 26000)}{8 \times 600}$	= 48.75
2. Interest rate per hour = $\frac{(C + S)}{2} \times \frac{i}{H}$	$= \frac{(260000 + 26000)}{2} \times \frac{12}{100 \times 600}$	= 28.4
3. Cost of housing per hour = $\frac{S}{H}$	$= \frac{6000}{8 \times 600}$	= 10.0
4. Tax per hour = $\frac{T}{H}$	$= \frac{1200}{600}$	= 2.0
A. Fixed cost per hour = (1) + (2) + (3) + (4)		= 89.15
5. Repair cost per hour = $2\% \times \frac{C}{H}$	$= \frac{2}{100} \times \frac{260000}{8 \times 600}$	= 1.08
6. Driver cost per hour = $\frac{\text{Driver salary per year}}{H}$	$= \frac{43200}{600}$	= 72.0
B. Variable cost per hour = 5 + 6		= 73.08
II. Cost of operation of pulverizer cum spreader = fixed cost per hour (A) + variable cost per hour (B)	$= 89.15 + 73.08$	= 162.23

The cost of operation of FYM pulverizer cum spreader is the sum of cost of operation of the tractor (I) and the cost of operation of the pulverizing cum spreading machine (II) i.e. 562.06+162.23=724.29 approx. Rs.724 per hour, when the machine is used for dry FYM pulverizing cum spreading operation.

III. Field capacity of the FYM pulverizer cum spreader

Forward speed of the machine = 3 kmph

Spreading width of the machine = 1.575 m

Field capacity of the machine

= Forward speed of the machine × Effective width of the spreader

$$= 3000 \frac{\text{m}}{\text{h}} \times 1.575 \text{m}$$

$$= 4500 \frac{\text{m}^2}{\text{h}}$$

$$= 1.16 \frac{\text{acre}}{\text{h}}$$

IV. Cost of operation of FYM pulverizer cum spreader machine per acre

$$= \frac{\text{cost of operation of the machine per hour} \left(\frac{\text{Rs}}{\text{h}} \right)}{\text{Field capacity of the machine} \left(\frac{\text{acre}}{\text{h}} \right)}$$

$$= 724.29 \frac{\text{Rs}}{\text{h}} / 1.16 \frac{\text{acre}}{\text{h}}$$

$$= 620.354 \frac{\text{Rs}}{\text{acre}}$$

V. Cost of spreading of FYM in Traditional practice

FYM applied = 2.5 tonnes per acre

Man – hours required for spreading of 2.5 tonnes of heaped FYM per acre = 12 h

$$\text{Wages per person} = 42 \frac{\text{Rs}}{\text{h}}$$

$$\text{Cost of hauling \& unloading of FYM per acre} \left(\frac{\text{Rs}}{\text{acre}} \right)$$

= Cost of operation of FYM pulverizing cum spreading operation per acre (IV)

$$= 620.354 \frac{\text{Rs}}{\text{acre}}$$

Cost of manual spreading of heaped FYM $\left(\frac{\text{Rs}}{\text{acre}}\right)$

= Man – hours required for spreading of 2.5 tonnes of heaped FYM per acre(h)

× Wages per person $\left(\frac{\text{Rs}}{\text{h}}\right)$

$$= 12 \times 42 = 504 \left(\frac{\text{Rs}}{\text{acre}}\right)$$

The cost of traditional practice of spreading of FYM is the sum of cost of hauling & unloading of FYM and cost of manual spreading of heaped FYM i.e. $620.354+504=1124.35$ approx. Rs.1124 per acre

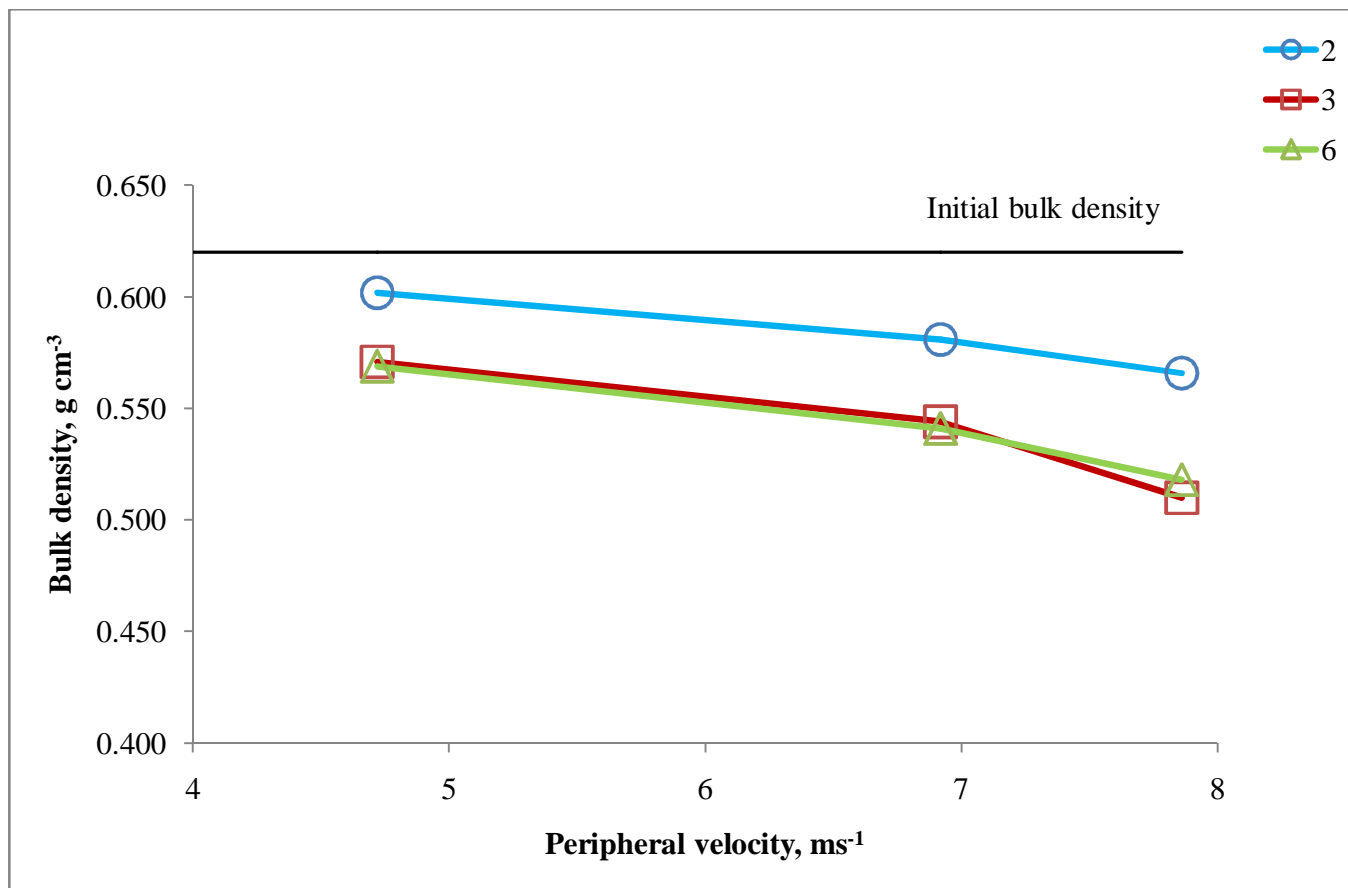


Fig 4.1 Effect of machine and operational parameters on bulk density at half shutter opening

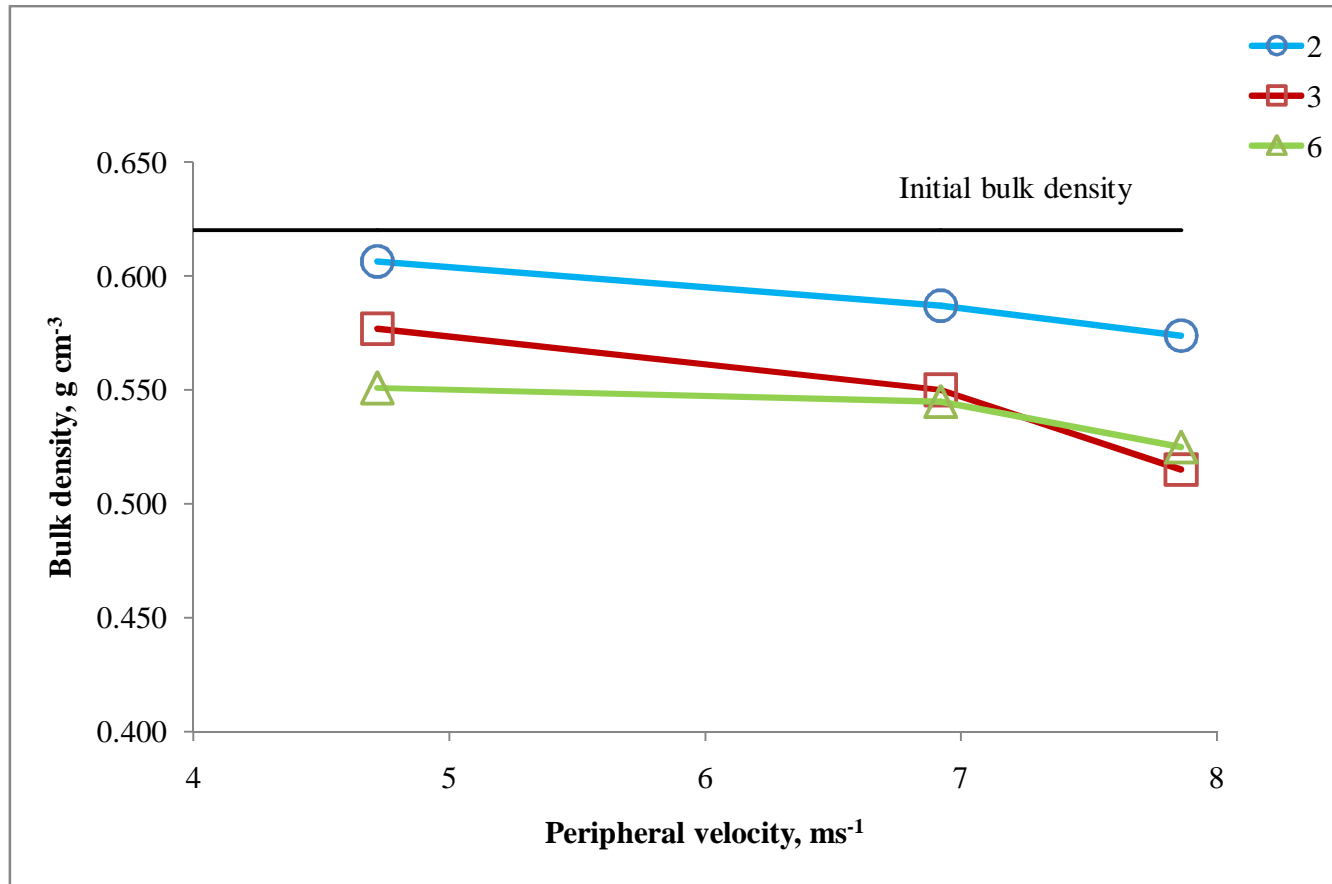


Fig 4.2 Effect of machine and operational parameters on bulk density at full shutter opening

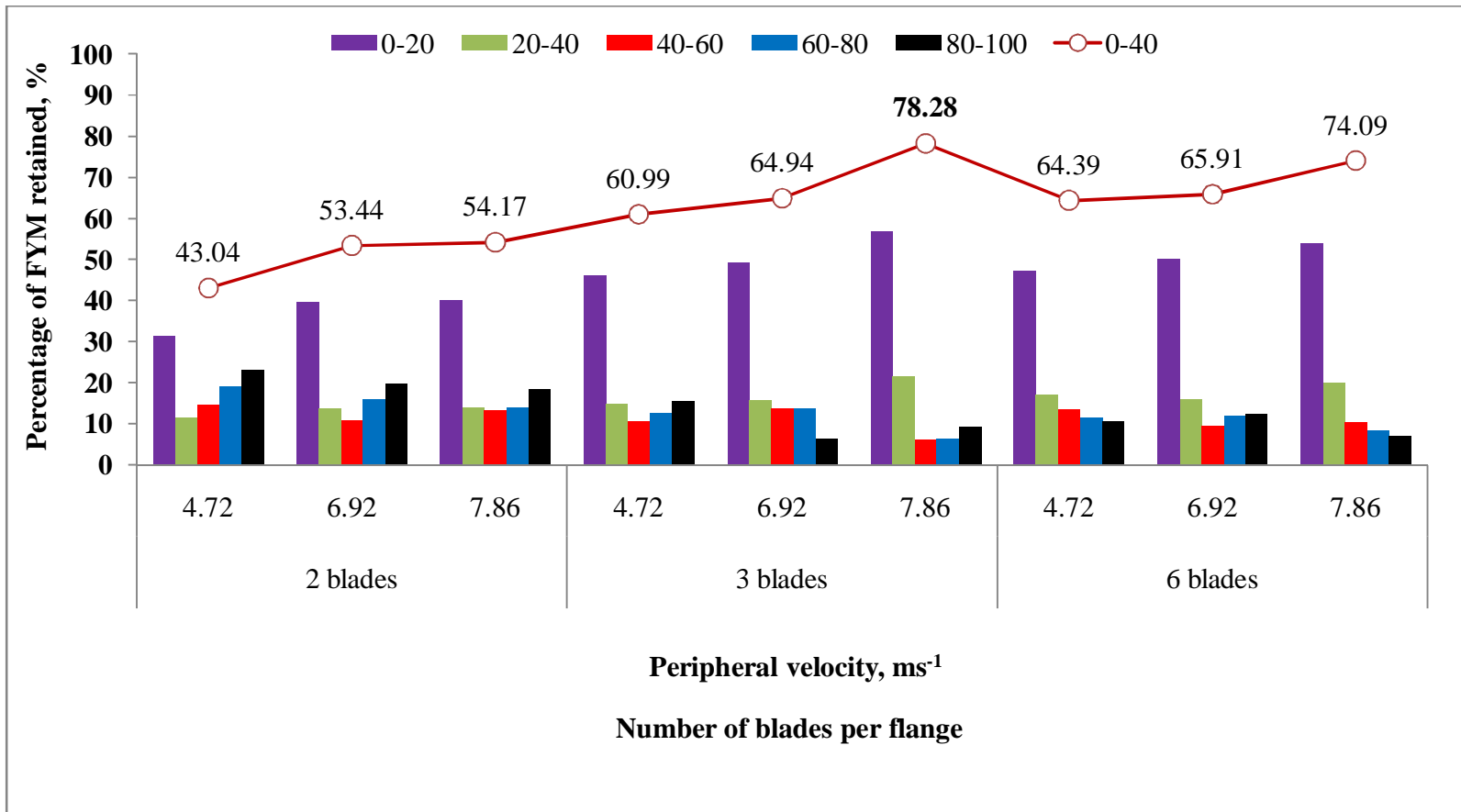


Fig. 4.3 Effect of machine and operational parameters on clod size distribution at half shutter opening

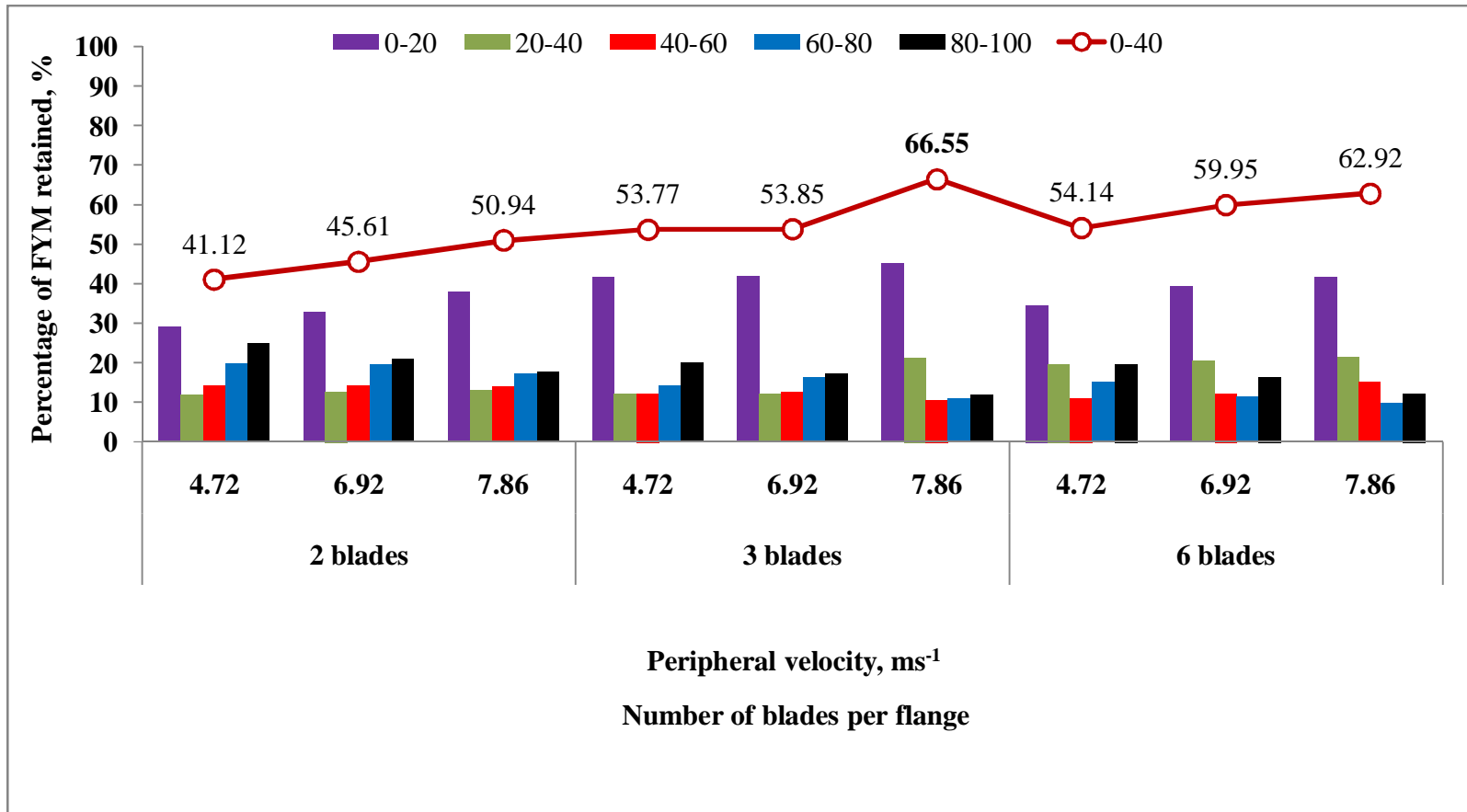


Fig. 4.4 Effect of machine and operational parameters on clod size distribution at full shutter opening

Chapter I

INTRODUCTION

Intensive cultivation of high yielding varieties of different crops requires application of plant nutrients in large quantities. In India, it is estimated that 20.2 million tonnes of the three major nutrients, namely nitrogen, phosphorous and potassium is removed by growing crops annually (Sinha, 2001). In addition, land degradation taking place through natural and manmade processes resulting loss of nutrients and lower food production (Sinha, 2001). To meet the enormous nutrient requirement, the supply of a large quantity of nutrients in the form of chemical fertilizers has got inherent limitations, negative impacts coupled with escalating prices, have led to growing interest in the organic manures as a source of nutrients. Manure is a useful soil amendment that can serve as a low cost source of organic fertilizer and as a soil conditioner that may ameliorate the soil properties for achieving soil health and productivity (Chambers *et al.*, 2001). Land application of manure can be beneficial as a means of recycling of nutrients and using organic matter contained in manure to raise and maintain the quality of soils for crop production (Schoenau & Aseefa, 2004).

1.1. JUSTIFICATION

Farmyard manure (FYM) is the oldest, and is still, undoubtedly, the most popular of all manures. Farmyard manure refers to the decomposed mixture of dung and urine of farm animals along with litter and left over material from roughages or fodder fed to the cattle. The ability of the farmyard manure to supply humus to the soil makes its use unavoidable. This job cannot be done by chemical fertilizers. Being tropical country, Indian soils are often deficient in humus which is an extremely important material formed after decomposition of farmyard manure. To build up a desired level of humus, organic manures must be applied to the field. Partially rotten FYM has to be applied three to four weeks before sowing, while well rotten manure applied immediately before sowing. Generally 10t ha⁻¹ to 20t ha⁻¹ is applied to fodder grasses and vegetables (Reddy and Reddy, 2010). In India production and availability of FYM is about 2850.503 lakh tonnes which is more as compared to other manure production (NCOF, 2012) and NPK contents of the FYM are shown in Table 1.1.

Table 1.1. Nutrient contents of FYM

S. No.	Nutrient	% content
1	Nitrogen (N)	0.5
2	Phosphorus (P ₂ O ₅)	0.2
3	Potash (K ₂ O)	0.5
4	Micronutrients	Moderate

Source: Reddy Y.T & S.G.H Reddy, (2010)

The application of manure has become mechanised in other countries like other field operations but in India, the indigenous methods are still followed, i.e. loaded trolley or bullock cart is moved in the field and stopped at regular interval where a man other than the driver unloads a small amount of manure and drops it in the form of a heap. These heaps are later spread around manually with spades, which is a laborious, tedious, uneconomical and time consuming process. The existing practice of leaving manure in small heaps scattered in the fields prior to the field application for a very long period lead to loss of nutrients. These losses can be reduced by spreading the manure and incorporating by ploughing immediately after application (Reddy & Reddy, 2005). The problem faced in the application of manure during the indigenous method is the non uniform application rate and non disintegration of large manure clumps.

Composting is a method of speeding up the natural decomposition process. The breakdown of manure and bedding occurs much more rapidly in the compost pile because the environment can be made ideal for the microbes to do their work. The end result of composting is a dark, crumbly, earthy-smelling product similar to potting soil. It was observed that during manual application of manure to the fields, there were many large manure clods were left un-decomposed, even after the piled manure was left to decay several weeks. This might be due to the conditions that were not favoured for piled manure under which it is permitted to decay. Compost fertilizer manufacturing industries use compost turners, manure pulverizers etc., for proper aeration, faster and complete decomposition of piled manure, which is under decomposing stage. These equipments are more costly and cannot be afforded by the small and marginal farmers. Manure gets decomposed as soon as it hits the ground by the microorganisms in the soil and environment. To speed up the decomposition process, it is necessary to break up the manure clods and make the more surface area expose to the micro organisms. Lesser the manure clod size better the surface area exposed for the attack of micro organisms. Hence, it is necessary to pulverise the manure when it applied to the land. In an attempt,

for solution to problems with indigenous method of manure application and to pulverize the large un-decomposed manure clods, an implement was developed at Regional Agricultural Research Station (RARS), Nandyal to pulverize and spread the solid organic manure simultaneously in the field, which is compatible to the tractor operated tipping trailer will be a milestone for the mechanisation of Indian farms.

Appropriate equipment adapted to the physical characteristics of different types of manure products are required in order to lower the risk of surface and ground water contamination from the excess nutrient application. To ensure intended amount of nutrients in solid manure has to be applied to the crop, it is important that the machinery is chosen, calibrated and operated to give accurate application. This means that it should be capable of being set up to apply $\text{m}^3 \text{ha}^{-1}$ or t ha^{-1} and to produce an acceptably even spread pattern. Research studies suggest that slurry tankers and manure spreaders should be chosen and operated in such a way that the coefficient of variation (CV) of the uniformity of the spreading is less than 25% (Chambers *et al.*, 2001). Three main types of solid manure spreaders are commonly used.

1.1.1. Rota spreader – a side discharge spreader which features a cylindrical body and a PTO-driven shaft fitted with flails running along the centre of the cylinder. As the rotor spins, the flails throw the solid manure out to the side.

1.1.2. Rear discharge spreader – a trailer body fitted with a moving floor or other mechanism which delivers solid manure to the rear of the spreader. The spreading mechanism can have either vertical or horizontal beaters, plus in some cases spinning discs.

1.1.3. Dual purpose spreader – a side discharge spreader with an open top V-shaped body capable of handling both slurry and solid manure. A fast spinning impeller or rotor, usually at the front of the spreader, throws the material from the side of the machine. The rotor is fed with material by an auger or other mechanism fitted in the base of the spreader and a sliding gate controls the flow rate of the material onto the rotor.

The optimal recycling of FYM to land requires an appropriate understanding of the complex network of parameters that governs the machine manure interactions. Also one of the primary conditions required to make the optimal use of FYM is the ability to control the rate on manure land application equipment, especially on machines designed to work with solid and semi-solid manure, since none of the readily available machine

performs adequately with respect to criteria (Hubert Landry, 2005). Moreover, manure land application equipment needs to be economically viable in terms of capital and operating costs and the economic benefits associated with the recycling of manure and manure by-products (Barnett, 1991).

For technological solutions, allowing the pulverization, uniform FYM distribution and optimal FYM land application operation, it is necessary to gain good understanding of FYM physical characteristics. Then, the interactions between the FYM and the mechanical components of the machine along with their operational parameters must be studied. Keeping these things in view, research work was undertaken on the performance evaluation of farmyard manure pulveriser cum spreader developed at RARS, Nandyal with the following specific objectives.

1.2. OBJECTIVES

- I. To study the influence of the machine and operational parameters on FYM characteristics and application rate.
- II. To optimize the machine and operating parameters for effective performance of the FYM Pulverizer cum Spreader.
- III. To develop a prototype FYM Pulverizer cum Spreader
- IV. To analyze the cost economics of FYM Pulverizer cum Spreader.

LIST OF ABBREVIATIONS AND SYMBOLS

approx.	: Approximately
cm	: Centimetre
<i>et al.</i> ,	: and others
fig	: Figure
g cm^{-3}	: Grams per cubic centimetre
h	: Hours
ha h^{-1}	: Hectare per hour
i.e.	: That is
kg m^{-3}	: Kilogram per cubic metre
kg s^{-1}	: Kilogram per second
km	: Kilometre
kW	: Kilowatt
km h^{-1}	: Kilometre per hour
m	: Metre
ms^{-1}	: Metre per second
m min^{-1}	: Metre per Minute
mm	: Millimetre
$\text{m}^3 \text{ ha}^{-1}$: Cubic metre per hectare
rpm	: Revolutions per minute
rad s^{-1}	: Radians per second
Rs	: Rupees
Rs lit^{-1}	: Rupees per litre
t ha^{-1}	: Tonne per hectare
viz.,	: Namely
yrs	: Years
&	: And
%	: Percent
°	: Degree

Chapter III

MATERIALS AND METHODS

In this chapter, FYM requirement of different soils is described and the description of the methodology adopted for the measurement of physical properties of FYM is explained. The constructional details of the FYM pulverizer cum spreader are explained. The experimental procedure carried out for the performance evaluation of machine (FYM pulverizer cum spreader) to obtain bulk density, clod size distribution and application rate was reported. The details of the selection of machine and its operational parameters for the evaluation of machine and the levels of parameters are enumerated. The method followed to optimize the selected levels of parameters for effective performance of the machine is narrated. Finally, the standard used for the calculation of cost of operation of FYM spreader is reported.

3.1. FYM REQUIREMENT OF DIFFERENT SOILS

Though the application of manure has become mechanized in other countries like other field operations, but in India, the application of FYM is done manually. First, the loaded trolley or bullock cart with FYM is stopped at average distance of 5 m and unloads 100 to 150 kg of FYM in the form of a heap. Later, these heaps are spread around manually with spades. The application of FYM varies according to the agro-climatic conditions, cropping pattern and availability of water source. Generally, the application of FYM varies from 5-8 t ha⁻¹ where the rainfall is less than 760 mm per annum and can be applied to 10-13 t ha⁻¹ in high rainfall areas. The aim of using the FYM pulverizer cum spreader is to apply manure more uniformly in the field at desired agronomic rates in a pulverized form.

The application rate of FYM was observed for different crops according to the agronomic conditions of Andhra Pradesh state. The components of the machine were developed to suit the varied dosages of FYM without much variation in the distribution efficiency. The recommended rate of application for different soils is given in Table 3.1

Table 3.1. Requirement of FYM based on agronomic conditions of soil

S. No.	Agronomic conditions of soil	Application rate (t ha ⁻¹)	
		Minimum	Maximum
1	Rainfall less than 760 mm	5	8
2	Rainfall more than 760 mm	10	13

3.2. PHYSICAL PROPERTIES OF FYM

After development of FYM pulverizer cum spreader initial trials were conducted at RARS, Nandyal to check the working of the machine with the wet FYM. It was observed that the wet FYM does not move freely from the equipment. Hence, it was decided to conduct the present investigation with dry FYM. Therefore, FYM was sun dried on a concrete flat form for a week and covered with a tarpaulin sheet whenever rain occurred. The drying of FYM improves the physical properties and encourages the machine performance as the physical properties of the FYM influence the machine performance. The important physical properties are moisture content, bulk density, angle of repose, coefficient of friction of FYM. The detailed procedure for the measurement of physical properties of dry FYM was described below.

3.2.1 Moisture Content

Moisture content of FYM is an important factor affecting the pulverization and application rate of manure. The moisture content of the FYM was determined by using the standard procedure.

FYM samples of each 20 g were taken in a known weight of container and placed in the oven at 110 °C and dried for 24 hours. Dried samples along with containers were weighed and noted down. Moisture contents of samples on wet basis were measured by using the formula

% Moisture content (wet basis):

$$= \frac{(\text{weight of undried sample} + \text{container}) - (\text{weight of dried sample} + \text{container})}{(\text{weight of undried sample} + \text{container}) - (\text{weight of container})}$$

3.2.2 Bulk Density

The bulk density of the manure is expected to have an effect on the spreading distance, pulverization, clod size distribution and application rate. The bulk density of the FYM was determined by using the standard procedure.

A core sampler of 10 cm diameter and 15 cm height was taken and driven vertically into the pit by gently hammering the wooden plate placed over it. The FYM around the ring was removed up to the bottom and core sampler was removed gently from the pit. The collected sample was weighed on an electronic balance. The bulk density of FYM was calculated by the formula

$$R = \frac{Q}{V}$$

$$V = \pi r^2 h$$

Where,

R = Bulk density, gcm^{-3}

Q = Weight of FYM in the measure, g

V = Volume of FYM, cm^3

r = Radius of core sampler, cm

h = Height of the core sampler, cm

3.2.3 Angle of Repose

The angle of repose of manure or solid material has considerable effect on the sliding of the manure. The angle of repose of FYM was determined by developing an inclined plate apparatus at CAE, Bapatla. The inclined plane was fabricated using an aluminium sheet of 300 mm length and 150 mm breadth with 25 mm height of side wall as shown in Plate 3.1. The two plates were placed one over the other and hinged at one end for easy movement of the plate. The angle of the plate is achieved by using a screw fixed at the center of the top plate. The protractor halves fixed at one end of the plates to read the angle of repose. A mild steel (MS) sheet was placed over the aluminium plate to study the angle of repose, as the surface material used for the fabrication of machine was made of MS sheet material.

FYM sample was placed on the MS sheet of the inclined plate apparatus shown in plate 3.1 and the top plate is gently raised. The angle at which the sample started sliding over the MS plate was noted down from the protractor with the sensitivity of one degree. The test was repeated for five times and the mean value was taken as the angle of repose.

3.2.4 Coefficient of Friction

The Coefficient of friction of FYM was determined using the angle obtained from the angle of repose experiment. The tangent of the angle of inclination gives the coefficient of friction between manure and the contact material and is given by the equation

$$\mu = \tan (\theta)$$

Where,

μ = Coefficient of friction

θ = Angle of repose, degrees

3.3. CONSTRUCTIONAL DETAILS OF FYM PULVERIZER CUM SPREADER

FYM pulverizer cum spreader attachment to the existing tractor trailer developed at RARS, Nandyal consisted of a two-wheel tractor-trailer, manure tub, hydraulically operated push blade, gear box, feed control shutter, spreader assembly, chain and sprocket system, spreader assembly and semi circular grill. The side and front view of the manure spreader is shown in Plates 3.2 and 3.3 respectively. The details and specifications of the components were as follows.

3.3.1 Two- wheeled Trailer

The trailer was provided with two pneumatic tyres of size 10 × 20 16 PR to support the loaded trailer with minimum compaction. The hitch of the trailer was provided with adjustable parking stand for convenient attaching and detaching of PTO shaft to the gearbox mounted on the main frame of the trailer.

3.3.2 Manure Tub

The tub of rectangular shape with dimensions $3150 \times 1825 \times 465$ mm was provided over the main frame with 5 ton capacity of FYM. At the front end, hydraulically operated manure push blade was fixed with the help of bolts and nuts. The spreader assembly along with the semicircular grill were mounted at the rear portion of the trailer. The entire arrangement was fitted with bolts and nuts to the trailer frame. This is done to enable to use as trailer, when not in use as FYM pulverizer cum spreader. The trailer frame is provided with 5 ton capacity hydraulic piston to raise or lower the manure tub to a maximum vertical angle of 87° to the horizontal plane of the frame.

3.3.3 Hydraulic Pump Operated Push Blade

FYM push blade of $1575 \times 457 \times 3$ mm made of MS was attached to a three ton capacity hydraulically operated cylinder to push the manure towards the spreader assembly fixed at the rear end of the trailer.

3.3.4 Gearbox Assembly

The gear box assembly consisted of two bevel gears oriented perpendicular to each other. The bevel gears were mounted on the input and output shafts and housed in the gearbox assembly using thrust bearings. Thus required gear reduction was obtained to the output shaft of the gearbox assembly when attached to the tractor PTO to the gearbox input shaft through cardon shaft.

3.3.5 Feed Control Shutter

Feed control shutter made up of galvanized iron (G.I) sheet of size $1727 \times 610 \times 3$ mm was mounted in the rear end of the manure tub to control the amount of manure fed to the spreader. The door opening area was adjusted from 100 mm to 400 mm depending on the condition of the FYM. The shutter opening height needed to be calibrated for accurate application of manure.

3.3.6 Spreader Shaft Assembly

The spreader shaft assembly consisted of six mild steel flanges of 250 mm diameter and 10 mm thick welded to the shaft. The spacing between the flanges was fixed at 300 mm to avoid overlap of the blades mounted on the successive flanges. Provision was made to fix two to six numbers of blades on the flange by using bolts and nuts. L- Shaped blades were fitted due to the fact that the blades possessing more horizontal surface area experience more material-metal contact resulting greater degree of acceleration of manure particles and pulverization. The entire assembly was mounted on the frame using thrust bearings.

3.3.7 Semicircular Grill Assembly

A semicircular shaped grill width of 1600 mm made of mild steel square rods of 12 mm thick with 100 mm × 100 mm openings. The entire semi circular grill was mounted on a U-channel fitted to the chassis frame through bolts and nuts.

3.3.8 Chain and Sprocket Assembly

Gearbox output shaft and spreader shaft were connected through a chain and sprocket system. The power was transmitted from the tractor PTO to the gearbox through cardon shaft and from the gearbox output shaft to spreader shaft through a chain and sprocket system. The desired speeds were obtained by changing the sprockets on the shaft.

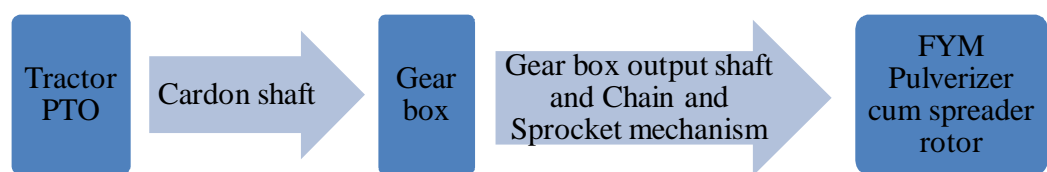


Fig 3.1 Power transmission system of FYM pulverizer cum spreader

3.4 OPTIMIZATION OF OPERATIONAL PARAMETERS

It is desirable to investigate the effect of material parameters viz. bulk density, moisture content, angle of repose and coefficient of friction and operational parameters, namely forward speed, peripheral speed of rotor, number of blades per flange of rotor and flow opening positions on the clod size distribution and application rate. This involves

various levels of above mentioned variables and their interactions. Hence, the developed tractor operated pulverizer cum spreader was tested at desired levels of operational parameters to determine the various factors affecting the performance. The entire experiment was conducted in the laboratory at stationary and also at field conditions. Based on the results, a prototype pulverizer cum spreader was developed and was field evaluated with the optimized operational parameters.

3.4.1 Selection of Different Levels of Machine and Operational Parameters

3.4.1.1 Flow opening area

The application rate of the FYM varies depending upon the type of soil, crop and agronomic practices. Considering the minimum and the maximum application rate and average forward speed of operation, provision was made in the pulverizer cum spreader unit to change the flow rate. Field trials were conducted at 1/4th, 1/2 and full opening of the shutter, the application rate was estimated. The results showed that the minimum and maximum application rates recommended for different soils could be achieved by changing the flow opening area from half to full opening of the shutter. Hence two flow opening areas of half and full were chosen for further investigation.

3.4.1.2 Forward speed of operation

The speed of operation of the tractor with trailer under field condition varies from 2 to 5 Km h⁻¹. In this investigation, the tractor with trailer attachment was operated in the field for a known distance of 30 m and the time taken to cover the distance was recorded at known tractor engine rpm and the forward speed of operation was calculated. The experiment was repeated at different engine rpm and the required forward speeds of 2.0, 3.0 and 5.0 Km h⁻¹ were determined.

3.4.1.3 Rotor peripheral velocity

Generally rotor with rotor diameter 450 to 500 mm is operated at rotor speeds of 180 to 300 rpm to prepare speed bed. Hence three rotor speeds of 200, 240 and 300 rpm within the prescribed level of peripheral velocities of 4.72 ms⁻¹, 6.92 ms⁻¹ and 7.86 ms⁻¹ respectively were selected for a 450 mm diameter. The required peripheral velocities 4.72 ms⁻¹, 6.92 ms⁻¹ and 7.86 ms⁻¹ were obtained by changing suitable chain sprocket drive. The required peripheral velocities of 4.72 ms⁻¹, 6.92 ms⁻¹ and 7.86 ms⁻¹ were obtained by changing the sprockets on rotor shaft to the corresponding engine rpm.

3.4.1.4 Number of blades per flange

The number of blades used per flange in a rotavator for tilling the soil is six. In the present study 2, 3, and 6 blades per flange were used to select the best combinations in terms of FYM pulverization cum distribution.

Table 3.2. Different variables considered for optimization of pulverizer cum spreader

S. No.	Parameters	Variables	Levels
1	Factors	Number of blades per flange (N)	2, 3, 6
		Peripheral velocity of the rotor (V), ms ⁻¹	4.72, 6.92, 7.86
		Forward speed of the rotor (F), Km h ⁻¹	2.0, 3.0, 5.0
		Shutter opening area	Half opening Full opening
2	Affected or Response variables	Bulk density, g cm ⁻³	--
		Clod distribution, mm	--
		Application rate, t ha ⁻¹	--

3.5 MEASUREMENT OF BULK DENSITY

Bulk density is taken as an index of FYM compaction and it was measured before and after each experiment. In order to ascertain the uniformity in FYM condition, the samples were collected randomly at three different locations by means of core sampler of 10 cm diameter and 15 cm height.

The FYM pulverizer cum spreader was powered to rotate till the desired speed attained. The manure tub was gradually raised at selected shutter opening area and engine rpm corresponding to desired forward speed. After completion of the experiment, the samples were collected randomly from the spreaded material at three different locations by means of core sampler. The samples then collected were weighed on an electronic balance and bulk density was calculated by the equations given in the section 3.2.2. The same procedure was repeated for all the other treatments and the readings were tabulated.

3.6 MEASUREMENT OF CLOD SIZE DISTRIBUTION

FYM samples were collected randomly at three different locations from the pulverized material by means of a rectangular open pan. The collected pulverized FYM samples were air dried on a tarpaulin for a period of 24 hours.

Clod size distribution was determined through sieve analysis. Sieve sizes of 20 mm, 40 mm, 60 mm, 80 mm, 100 mm and pan was used to conduct the experiment. The sieves were arranged on a wooden table as shown in plate 3.4 in ascending order of the sieve openings from bottom to top. The air dried FYM samples were kept on the top screen over a platform and sieved for 2 to 3 minutes. The weight of the FYM retained on the each sieve was observed and tabulated. The same procedure was repeated for all the treatments by operating at desired levels.

3.7 MEASUREMENT OF APPLICATION RATE

Measurement of application rate of FYM was determined by conducting the experiment under the field condition. The pulverizer cum spreader was run on a tarpaulin sheet with grid of 100cm × 100cm was marked with a chalk piece at three different locations. The location of the grid was selected so that the discharge represents the entire width of the trailer. The FYM collected in the grid was weighed. The experiment was repeated for all the treatments at half and full shutter opening area.

3.8 DEVELOPMENT OF PROTOTYPE FYM PULVERIZER CUM SPREADER

A prototype FYM pulverizer cum spreader was developed based on the optimized values of machine and operational parameters obtained from the selected levels of variables. The prototype consisted of a two-wheel tractor-trailer, manure tub, hydraulically operated push blade, gear box, feed control shutter, spreader rotor assembly, chain and sprocket system and semi circular grill.

3.9 FIELD EVALUATION OF FYM PULVERIZER CUM SPREADER

Performance evaluation of the prototype FYM pulverizer cum spreader was conducted in the field with the best optimized machine and operational parameters derived from the experimental trials conducted under stationary and field conditions. The application rate, bulk density and clod size distribution were observed at half and full shutter opening area.

3.10 COST OF OPERATION OF FYM PULVERIZER CUM SPREADER

Tractor of 60 HP was used for the operation of the FYM pulverizing cum spreading machine. The total cost of FYM pulverizing cum spreading operation is the sum of cost of operation of tractor and the machine. The fixed and variable costs of operation of tractor and the machine were calculated as per the IS: 9164- 1979 code with the values presented in the Appendix I.



Plate 3.2 Front View of FYM pulverizer cum spreader



Plate 3.3 Side View of FYM pulverizer cum spreader



Plate 3.1 Inclined plate apparatus



Plate 3.4 Sieves

LITERATURE CITED

- Agnew, J.M., Leonard, J. J., Feddes, M and Feng, Y. 2003. A modified air pycnometer for compost air volume and density determination. *Canadian Biosystems Engineering*, 45(6): 27-35.
- Barnett, G.M. 1991. Deleterious effects of animal manure. In *Proceedings of the National Workshop on Land Application of Animal Manure*, eds. D.A. Léger, N.K. Patni and S.K. Ho, 55 - 84. Ottawa, ON: Canadian Agricultural Research Council.
- Chambers, B., Nicholson, N., Smith, K., Pain, B., Cumby, T and Scotford, I. 2001. *Spreading systems for solid manure*. MAFF: Managing Livestock Manures. Booklet 3. Wolverhampton, U.K.
- Destain, M. F and Houmy, K. 1990. Effects of design and Kinematic parameters of rotary cultivators on soil structure, *Soil and Tillage Research*, 17:291-301.
- Duhonik, J., Benedièiè, J and Bernik, R. 2004. Analysis and Design Parameters for Inclined Rotors used for Manure Dispersal on Broadcast Spreaders for Solid Manure. *Transactions of ASAE*. 47(5): 1389-1404.
- Duhonik, J., Benedièiè, J and Bernik, R. 2006. Side delivery spreading of manure. *Transactions of ASAE*. 49(6): 1663-1675.
- EI-Sharabasy, M. M. A., Ali, M. M. A and Afify, M. K. 2007. Manufacturing and evaluation of self-propelled machine for broad casting seeds and granular fertilizers. *Misr J. Ag. Eng.* 24(4): 752-774.
- Fasina, O.O. 2006. Flow and Physical Properties of Switchgrass, Peanut Hull, and Poultry Litter. *Transactions of ASABE*. 49(3): 721-728.
- Fulton, J.P., Shearer, S.A., Higgins, S. F., Hancock, D. W and T.S. Stombaugh. 2005. Distribution pattern variability of granular VRT applicators. *Transactions of ASAE* 48(6): 2053-2064.
- Glancey, J.L and Hoffman, S. C. 1996. Physical properties of solid waste materials. *Applied Engineering in Agriculture*, 12(4): 441-446.
- Glover, J.W and Baird, J. V. 1973. Performance of spinner type fertilizer spreaders. *Transactions of ASAE*. 16(1): 48-51.

- Hoftsee J.W and Huisman, W. 1990. Handling and spreading of fertilizers Part 1: Physical properties of fertilizer in relation to particle motion. *J. Agri. Eng. Res.* 47(1): 213-234.
- Hubert Landry. 2005. Numerical modeling of machine-product interactions in solid and semi-solid manure handling and land application. *Ph.D.* Thesis submitted to College of Graduate Studies and Research, University of Saskatchewan, Saskatoon.
- Indian standards. 1979. IS 9164 : *Guide for estimating farm machinery cost of operation*. Indian standard institution, New Delhi.
- Joseph Reddy, S. 2010. Investigation on the effect of soil machine and operational parameters towards the development of a rotary strip till drill. *Ph.D.* Thesis submitted to Tamil Nadu Agricultural University, Coimbatore.
- Landry, H., Laguë, C and Roberge, M. 2003. Engineering properties of solid and semi-solid livestock manure as related to the modelling of machine-product interactions in handling and land application equipment. ASABE Paper No. 1111505. St. Joseph, MI: ASABE.
- Landry, H., Laguë, C and Roberge, M. 2004. Physical and rheological properties of manure products. *Applied Engineering in Agriculture* 20(3):277-288
- Lee, K. S., Park, S. H., Park, W.Y and Lee, C. S. 2003. Strip tillage characteristics of rotary tiller blades for use in dry land direct rice seeder. *Soil and Tillage Research*, 71(1): 25-32
- Malgeryd, J and Wetterberg, C. 1996. Physical properties of solid and liquid manures and their effects on the performance of spreading machines. *Journal of Agricultural Engineering Research*, 64: 289-298.
- Mitchell, C.C and Donald, J. O. 1995. *The Value and Use of Poultry Manures as Fertilizers*. Alabama Cooperative Extension Service (ACES) Circular ANR-244.
- Mitchell, C.C and Tyson, T. W. 2001. *Calibrating poultry litter spreaders*. Alabama Cooperative Extension System: ANR-889.
- Mohamed Ali Tawfik and Islam M. M. Khater. 2009. Best management practices affecting the performance of a twin disc fertilizer spreader in new reclaimed Areas. *Misr J. Ag. Eng.* 26(1): 624-642.

- NCOF, 2012. National Project on Organic Farming Annual Report. National Centre of Organic Farming (NCOF), Department of Agricultural cooperation, Ministry of Agriculture, Govt. of India, Ghaziabad.
- Parish, R.L. 2000. Spreader rate determination from pattern tests compared with rate calibration. *Applied Engineering in Agriculture*. 16(2): 119-120.
- Pezzi, F and Rondelli, V. 2002. Evaluation of a Prototype Spreader in the Distribution of Poultry Manure. *Applied Engineering in Agriculture*. 18(3): 285-291.
- Picaud, D. 2001. Importance des caractéristiques des fumiers sur les performances d'épandage. Unpublished report. École Nationale d'Ingénieurs des Travaux Agricoles, Clermont-Ferrand, France.
- Rynk, R. 1992. *On-farm Composting Hand book*, North east Regional Agricultural Engineering Service, NRAES-54:9-10.
- SAF. 1999. Farm Facts: *Nutrient values of Manure*. Saskatchewan Agriculture and Food (SAF) Fact Sheet, ISSN 0840-9447. Regina, SK: Saskatchewan Agriculture and Food.
- Schoenau, J. J and Aseefa, B. 2004. *Land application and handling of manure*. In: Amrani, M., Ed., *Manure research findings and technologies*, AAFRD Technical press, Edmonton, 97-140.
- Sherman, R. 1999. *Large scale organic materials* composting. North Carolina cooperative extension service, AG-593:3.
- Shiva Bhambota., Gurusahib Singh Manes., Apoor Prakash and Anoop Dixit. 2014. Effect of blade shape and rotor speed of rotavator on pulverization and mixing quality of soil. *Agricultural Engineering Today*. 38(4): 25-30
- Singh, R.C and Singh, C. D. 2013. Development and Performance Testing of a Tractor Trailer-cum-Farmyard Manure Spreader. *Agricultural Mechanization in Asia, Africa and Latin America*. 37(2): 1-6.
- Sinha, S. 2001. India: *State of the Environment*. United Nations Environment Programme, Thailand. 69.
- Suthakar, B., Kathrivel, K., Manian, R and Manohar Jesudas, D. 2008. Development and performance evaluation of manure spreading attachment to two wheel trailer. *Agricultural Mechanization in Asia, Africa and Latin America*. 39(3): 22-28.

Thirion F., Chabot, F and Andeler, D. 1998. Determination of physical characteristics of animal manure. *Proceedings of RAMIRAN 98 (8th International Conference on Management Strategies for Organic Waste Use in Agriculture) Rennes, France.* 457 –469.

Wilhoit, J.H., Bannon, J.S., Duffield, R.R and Q. Ling. 1994. Development and Evaluation of a Drop Applicator for Poultry Litter. *Applied Engineering in Agriculture.* 10(6): 777-782.

Yellamanda Reddy, T and Shankara Reddy, G.H. 2010. Principles of Agronomy. Kalyani Publishers, New Delhi. 203-205.

Note: The literature is cited as per the “Thesis Guidelines” prescribed by Acharya N.G. Ranga Agricultural University, Rajendranagar, Hyderabad-500 030.

Chapter IV

RESULTS AND DISCUSSION

In this chapter, the physical properties of Farmyard manure (FYM) pile were summarised. The influence of operational and machine parameters viz., Forward speed, Rotor speed and no. of blades per flange of rotor at half and full shutter opening on bulk density, pulverization and application rate of FYM were analyzed and narrated. Optimization of selected levels of variables was enumerated. The cost of operation of Farmyard manure pulverizer cum spreader is reported.

4.1 PHYSICAL PROPERTIES OF FYM

Physical properties of FYM affect the performance of the pulverizing cum spreading machines. The physical properties of FYM used for the experiment were measured and are presented in Table 4.1

Table 4.1. Physical properties of FYM

S. No.	Physical properties of FYM	
1	Moisture content (%)	21
2	Initial Bulk density (g cm ⁻³)	0.630
3	Angle of repose (degrees)	41
4	Coefficient of friction	0.87

4.2 EFFECT OF MACHINE AND OPERATIONAL PARAMETERS ON BULK DENSITY

The influence of the machine and its operational parameters viz., numbers of blades per flange and rotor peripheral speed at half and full shutter opening on bulk density were observed. Mean bulk density was calculated and tabulated for different combinations and graphs were drawn.

4.2.1 Effect of Machine and Operational Parameters on Bulk Density at Half Shutter Opening Area

The mean bulk density obtained for the different treatment combinations at half shutter opening are shown in Table 4.2 and Fig 4.1. It was observed that the bulk density decreased with increase in peripheral velocity and number of blades per flange of rotor. The decrease in bulk density is due to repeated re-tilling of the material due to increase of peripheral velocity and number of blades per flange (Matsou, 1961., Destain and Houmy, 1990., Joseph Reddy, 2010 and Shiva Bhambota *et al.*, 2014). The lowest bulk density of 0.510 g cm⁻³ was obtained at rotor peripheral velocity of 7.86 ms⁻¹(V₃) and 3 number of blades per flange (N₂). It was observed that there is no decrease in bulk density with increase of number of blades per flange from 3 to 6 at 7.86 ms⁻¹ peripheral velocity.

Table 4.2. Mean bulk densities at half shutter opening area for different levels

Shutter opening area (H)	Peripheral velocity (V), ms ⁻¹	Number of blades (N)		
		2 (N ₁)	3 (N ₂)	6 (N ₃)
Half open (H ₁)	4.72 (V ₁)	0.602	0.571	0.569
	6.92 (V ₂)	0.581	0.544	0.541
	7.86 (V ₃)	0.566	0.510	0.518

4.2.2 Effect of Machine and Operational Parameters on Bulk Density at Full Shutter Opening Area

The mean bulk density obtained for different treatment combinations at full shutter opening area are shown in Table 4.3 and Fig 4.2. It was observed that the bulk density decreased with increase in peripheral velocity and number of blades per flange of rotor. The decrease in bulk density is due to reduction in bite length due to increase in peripheral velocity and number of blades per flange (Matsou, 1961., Destain and Houmy, 1990., Joseph Reddy, 2010 and Shiva Bhambota *et al.*, 2014). The lowest bulk density of 0.515 g cm⁻³ was obtained at rotor peripheral velocity of 7.86 ms⁻¹(V₃) and 3 number of blades per flange. It was observed that there is no decrease in bulk density with increase of number of blades per flange from 3 to 6 at 7.86 ms⁻¹ peripheral velocity. The bulk density obtained at full shutter opening was higher when compared to the bulk density obtained at half shutter opening. This is mainly due to the free falling of the large amount of material (FYM) over rotor blades at full shutter opening.

Table 4.3. Mean bulk densities at full shutter opening area for different levels

Shutter opening area (H)	Peripheral velocity (V), ms ⁻¹	Number of blades (N)		
		2 (N ₁)	3 (N ₂)	6 (N ₃)
Full open (H ₂)	4.72 (V ₁)	0.606	0.577	0.551
	6.92 (V ₂)	0.587	0.550	0.545
	7.86 (V ₃)	0.574	0.515	0.525

4.2.3 Optimized Machine and Operational Parameters for Minimum Bulk Density at Half and Full Shutter Opening

Based on the experimental results, the treatment combinations of V₃N₂ yielded minimum bulk density at half and full shutter openings are presented in Table 4.4

Table 4.4. Best treatment combination for minimum bulk density

Shutter opening area (H)	Peripheral velocity (V), ms ⁻¹	Number of blades (N)	Bulk density (g cm ⁻³)
Half open (H ₁)	7.86 (V ₃)	3 (N ₂)	0.510
Full open (H ₂)	7.86 (V ₃)	3 (N ₂)	0.515

4.3 EFFECT OF MACHINE AND OPERATIONAL PARAMETERS ON CLOD SIZE DISTRIBUTION

The influence of the machine and its operational parameters viz., number of blades per flange and rotor peripheral speed at half and full shutter opening on clod size distribution was observed. Percentage of different sizes of clods was calculated and tabulated for different combinations and graphs were drawn.

4.3.1 Effect of Machine and Operational Parameters on Clod Size Distribution at Half Shutter Opening

The percentage of different clod sizes obtained for different treatment combinations at half shutter opening are shown in Table 4.5 and Fig 4.3. It was observed that the increase in peripheral velocity and number of blades, increased the percentage of minimum clod size distribution ranging from 0 to 40 mm. It was observed

that highest percentage of 78.28 of minimum clod size distribution in the range of 0-40 mm was obtained at rotor peripheral velocity of 7.86 ms^{-1} and 3 number of blades. Smaller manure particles have more surface area resulting in easily availability of nutrients to the micro organisms (Sherman, 1999 and Rynk, 1992). It was observed that there is decrease in percent of 0 to 40 mm clod size distribution with increase of number of blades per flange from 3 to 6 at 7.86 ms^{-1} peripheral velocity. This is mainly due to throwing action of the blades at higher number of blades per flange (Lee, 2003).

Table 4.5. Clod size distribution at half shutter opening for different levels

Sieve size (mm)	Percentage of FYM retained (%)								
	2 blades (N_1)			3 blades (N_2)			6 blades (N_3)		
	4.72 (V_1)	6.92 (V_2)	7.86 (V_3)	4.72 (V_1)	6.92 (V_2)	7.86 (V_3)	4.72 (V_1)	6.92 (V_2)	7.86 (V_3)
0-20	31.48	39.74	40.12	46.10	49.21	56.69	47.34	50.01	54.13
20-40	11.56	13.70	14.05	14.89	15.73	21.59	17.05	15.90	19.96
40-60	14.77	10.82	13.38	10.59	13.82	6.13	13.51	9.61	10.43
60-80	19.07	15.81	13.97	12.82	13.72	6.22	11.51	11.98	8.38
80-100	23.12	19.93	18.48	15.60	6.35	9.37	10.59	12.50	7.10
0-40	43.04	53.44	54.17	60.99	64.94	78.28	64.39	65.91	74.09

4.3.2 Effect of Machine and Operational Parameters on Clod Size Distribution at Full Shutter Opening

The percentage of different clod sizes obtained for the different treatment combinations at full shutter opening are shown in Table.4.6 and Fig 4.4. It was observed that the increase in peripheral velocity and number of blades increased the percentage of minimum clod size distribution ranging from 0 to 40 mm.

It was observed that highest percentage of 66.55 of minimum clod size distribution was obtained in the range of 0-40 mm at rotor peripheral velocity of 7.86 ms^{-1} and 3 number of blades. Smaller manure particles have more surface area

resulting in easily availability of nutrients to the micro organisms (Sherman, 1999 and Rynk, 1992). It was observed that there is decrease in clod size distribution with increase of number of blades per flange from 3 to 6 at 7.86 ms⁻¹ peripheral velocity. This is mainly due to throwing action of the blades at higher number of blades per flange (Lee, 2003).

The percentage of 0 to 40 mm clod size distribution obtained at full shutter opening was lower when compared to the clod size distribution obtained at half shutter opening. This is mainly due to the free falling of the large amount of material (FYM) over rotor blades at full shutter opening resulting large size clods.

Table 4.6. Clod size distribution at full shutter opening for different levels

Sieve size (mm)	Percentage of FYM retained (%)								
	2 blades (N ₁)			3 blades (N ₂)			6 blades (N ₃)		
	4.72 (V ₁)	6.92 (V ₂)	7.86 (V ₃)	4.72 (V ₁)	6.92 (V ₂)	7.86 (V ₃)	4.72 (V ₁)	6.92 (V ₂)	7.86 (V ₃)
0-20	29.15	32.9	37.87	41.71	41.78	45.24	34.55	39.36	41.53
20-40	11.97	12.71	13.07	12.06	12.07	21.31	19.59	20.59	21.39
40-60	14.20	14.12	13.96	12.21	12.63	10.54	11.05	12.25	15.11
60-80	19.75	19.46	17.31	14.09	16.31	10.9	15.13	11.50	9.72
80-100	24.93	20.81	17.79	19.93	17.21	12.01	19.68	16.40	12.25
0-40	41.12	45.61	50.94	53.77	53.85	66.55	54.14	59.95	62.92

4.3.3 Optimized Machine and Operational Parameters for Highest Percentage of 0 to 40 mm Clod Size Distribution at Half and Full Shutter Opening

Experimental results revealed that the treatment combination of V₃N₂ yielded highest percentage of 0 to 40 mm clod size distribution at half and full shutter openings are presented in Table 4.7.

Table 4.7. Best treatment combination for highest percentage of 0 to 40 mm clod size

Shutter opening area (H)	Peripheral velocity (V), ms ⁻¹	Number of blades (N)	Percentage of 0 to 40mm clod size distribution (%)
Half open (H ₁)	7.86 (V ₃)	3 (N ₂)	78.28
Full open (H ₂)	7.86 (V ₃)	3 (N ₂)	66.55

4.4 EFFECT OF MACHINE AND OPERATIONAL PARAMETERS ON APPLICATION RATE

The influence of the machine and its operational parameters viz., Forward speed of spreader, number of blades per flange of rotor and rotor peripheral speed at half and full shutter opening on application rate was observed under field condition. The observed readings were estimated and tabulated for different combinations and graphs were drawn.

4.4.1 Effect of Machine and Operational Parameters on Application Rate at Half Shutter Opening

The application rates obtained for the different treatment combinations at half shutter opening are shown in Table.4.8 and Fig 4.6. It was observed that when the forward speed increased from 2 km h⁻¹ to 5 Km h⁻¹, the application rate was decreased at particular peripheral velocity with specified number of blades of rotor (EI-Sharabasy *et al.*, 2007., Suthakar *et al.*, 2008., Mohamed Ali Tawfik and Islam M.M. Khater, 2009 and Singh R.C and Singh C.D. 2013). The highest application rate of 5.8 t ha⁻¹ was obtained at forward speed of 3 Km h⁻¹ (F₂), peripheral velocity of 7.86 ms⁻¹ (V₃) and 3 no of blades per flange of rotor. It was observed that at 7.86 ms⁻¹ (V₃) peripheral velocity and 6 number of blades per flange, the application rate decreased. This is mainly due to the obstruction caused by the blades to the free falling of material.

4.4.2 Effect of Machine and Operational Parameters on Application Rate at Full Shutter Opening

The application rates obtained for the different treatment combinations at full shutter opening are shown in Table.4.9 and Fig 4.7. It was observed that when the forward speed increased from 2 km h⁻¹ to 5 km h⁻¹, the application rate was decreased at

particular peripheral velocity with specified number of blades of rotor (EI-Sharabasy *et al.*, 2007., Suthakar *et al.*, 2008., Mohamed Ali Tawfik and Islam M.M. Khater, 2009 and Singh R.C and Singh C.D. 2013). The highest application rate of 12.6 t ha⁻¹ was obtained at forward speed of 3 km h⁻¹ (F₂), peripheral velocity of 7.86 ms⁻¹ (V₃) and 3 no of blades per flange. It was observed that at 7.86 ms⁻¹ (V₃) peripheral velocity and 6 number of blades per flange, the application rate decreased. This is mainly due to the obstruction caused by the blades to the free falling of material.

Table 4.10. Best treatment combination for Application rate

Shutter opening area (H)	Peripheral velocity (V), ms ⁻¹	Number of blades (N)	Forward speed (F), km h ⁻¹	Application rate (t ha ⁻¹)
Half open (H ₁)	7.86 (V ₃)	3 (N ₂)	3 (F ₂)	5.8
Full open (H ₂)	7.86 (V ₃)	3 (N ₂)	3 (F ₂)	12.6

4.5 OPTIMIZED VARIABLES TOWARDS THE DEVELOPMENT OF PROTOTYPE PULVERIZER CUM SPREADER

From the results, one combination each that resulted the minimum bulk density, maximum percentage of minimum clod size distribution in the range 0 to 40 mm and optimal discharge rate were selected at half and full opening of shutter area. The following optimized parameters were considered for the fabrication of the prototype pulverizer cum spreader.

Optimized parameters	Half opening size	Full opening size
Peripheral velocity, ms ⁻¹	- 7.86 (V ₃)	7.86 (V ₃)
Forward speed, km h ⁻¹	- 3 (F ₂)	3 (F ₂)
Number of blades per flange, No`s	- 3 (N ₂)	3 (N ₂)

4.6 FIELD EVALUATION OF THE PROTOTYPE PULVERIZER CUM SPREADER

The tractor operated prototype pulverizer cum spreader was evaluated for field performance with the best optimized variables derived from the experimental trails. The bulk density, clod size distribution and discharge rate were observed at half and full shutter opening area.

The bulk density, clod size distribution and application rate was observed as 0.512 g cm^{-3} & 0.521 g cm^{-3} , 75.99% & 64.45% and 5.9 t ha^{-1} & 12.5 t ha^{-1} at half and full shutter opening area respectively.

4.7. COST OF OPERATION OF FARMYARD MANURE PULVERISER CUM SPREADER

The operational cost of developed farmyard manure spreader was Rs.620 per acre, when the machine was used for dry FYM pulverizing cum spreading operation. The cost of hauling and spreading of dry FYM with the traditional method of spreading was Rs.1124 per acre . There was a saving of Rs.504 per acre over traditional method of spreading.

Table 4.8. Effect of machine and operational parameters on application rate at half shutter opening

S. No.	Forward speed (F), km h ⁻¹	Peripheral velocity (V), ms ⁻¹	Number of blades, (N)	Application rate, (t ha ⁻¹)
1	2 (F ₁)	4.72 (V ₁)	2 (N ₁)	3.2
2			3 (N ₂)	4.2
3			6 (N ₃)	3.9
4		6.92 (V ₂)	2 (N ₁)	3.5
5			3 (N ₂)	4.6
6			6 (N ₃)	4.3
7		7.86 (V ₃)	2 (N ₁)	4.8
8			3 (N ₂)	5.6
9			6 (N ₃)	5.3
10	3 (F ₂)	4.72 (V ₁)	2 (N ₁)	2.9
11			3 (N ₂)	3.6
12			6 (N ₃)	3.5
13		6.92 (V ₂)	2 (N ₁)	3.2
14			3 (N ₂)	4.7
15			6 (N ₃)	4.4
16		7.86 (V ₃)	2 (N ₁)	5.1
17			3 (N ₂)	5.8
18			6 (N ₃)	5.4
19	5 (F ₃)	4.72 (V ₁)	2 (N ₁)	1.1
20			3 (N ₂)	1.6
21			6 (N ₃)	1.4
22		6.92 (V ₂)	2 (N ₁)	1.8
23			3 (N ₂)	2.8
24			6 (N ₃)	2.5
25		7.86 (V ₃)	2 (N ₁)	2.1
26			3 (N ₂)	3.3
27			6 (N ₃)	2.5

Table 4.9. Effect of machine and operational parameters on application rate at full shutter opening

S. No.	Forward speed (F), km h ⁻¹	Peripheral velocity (V), ms ⁻¹	Number of blades, (N)	Application rate, (t ha ⁻¹)
1	2 (F ₁)	4.72 (V ₁)	2 (N ₁)	6.5
2			3 (N ₂)	8.3
3			6 (N ₃)	7.7
4		6.92 (V ₂)	2 (N ₁)	7.3
5			3 (N ₂)	9.6
6			6 (N ₃)	8.8
7		7.86 (V ₃)	2 (N ₁)	9.7
8			3 (N ₂)	12.4
9			6 (N ₃)	10.4
10	3 (F ₂)	4.72 (V ₁)	2 (N ₁)	5.6
11			3 (N ₂)	7.4
12			6 (N ₃)	6.9
13		6.92 (V ₂)	2 (N ₁)	6.6
14			3 (N ₂)	9.3
15			6 (N ₃)	9.1
16		7.86 (V₃)	2 (N ₁)	10.3
17			3 (N₂)	12.6
18			6 (N ₃)	10.7
19	5 (F ₃)	4.72 (V ₁)	2 (N ₁)	2.9
20			3 (N ₂)	3.8
21			6 (N ₃)	3.5
22		6.92 (V ₂)	2 (N ₁)	3.9
23			3 (N ₂)	5.9
24			6 (N ₃)	5.3
25		7.86 (V ₃)	2 (N ₁)	4.1
26			3 (N ₂)	6.8
27			6 (N ₃)	6.2

Chapter II

REVIEW OF LITERATURE

To meet nutrient requirements for crops, negative impacts coupled with escalating prices of inorganic fertilizers, the use of organic fertilizers has increased in crop production. In India, application of farmyard manure (FYM) to the agriculture fields has been generally accepted practice. FYM contains a significant source of nutrients and are inexpensive to attain, compared to inorganic fertilizers. Uniform and accurate application of FYM is essential to meet target rate established from nutrient management plan. Limited research has been done on land application of FYM type. Several areas of scientific literature related to different manure and similar product physical properties, their application rate determination methods, distribution patterns, uniformity and pulverization were reviewed to quantify the potential of using similar ideas when applying FYM. With specific objectives in mind, literature related to machine and operational parameters of different equipment affected the application rate and pulverization of products, their optimisation basis and the cost of operation were also reviewed.

2.1. PHYSICAL PROPERTIES OF MANURE

Knowledge on physical properties of FYM is fundamental in design and efficient operation of the conveyance and application systems. These include moisture content, bulk density, angle of repose, coefficient of friction etc.

Glancey and Hoffman (1996) studied the physical properties of solid organic by-products. The measured properties were bulk density, moisture content, angle of repose, maximum clump size and static frictional characteristics. Ranges of values were given for each property. They investigated trends in the measured properties to develop general guidelines for the design and analysis of material handling systems, transportation equipment and spreaders. They concluded that wet bulk density was dependent on moisture content for all the solid products evaluated and that knowledge of moisture content was therefore more important than the type of material. The static friction characteristics suggested that there was little practical difference between the different products. They also identified that all unscreened products contained large clumps.

Malgeryd and Wetterberg (1996) conducted research at Swedish National Machinery Testing Institute to study the effect of physical properties of manure on spreading performance of the machine. They reported that five manure parameters viz., bulk density, stacking ability or consistency, comminuting resistance, heterogeneity and dry matter content were important to study the solid manure spreader performance.

Thirion *et al.* (1998) reported that the performance of a spreader is directly related to the physical properties of the material being applied. They also studied the properties of manure including normal stress, shear stress, bulk density, friction coefficient, straw content and dry matter content. They reported that the physical properties of materials influence the performance of the machine.

Picaud (2001) studied the relations between the properties of organic by-products viz., density, penetration resistance and dry matter content with the performance of land application equipment. He reported that lower resistance to penetration yielded smaller coefficient of variations and improved the spreading performance of the spreader.

2.1.1. Moisture Content

Moisture content is a measure of the amount of water found within a product at any given time and is usually expressed in percent. There are two methods to represent moisture content, (1) Wet basis (wb) and (2) Dry basis (db). In the wet basis, moisture content is the ratio of the weight of water in the sample to the weight of total product sample multiplied by hundred. In dry basis, it is the ratio of the weight of water in the sample to the weight of dry matter of product sample. The amount of moisture naturally varies most in manure, and this variation depends on the age of the manure, and the conditions under which it is allowed to decompose. The moisture content of the manure determines the type of equipment used for manure handling. Manure may be classified into three types, as shown in Table 2.1 based on the moisture content.

Table 2.1. Manure Classification based on moisture content

Type of manure	Moisture content	Ease of pumping
Liquid	>90%	Easy to pump
Semi-Solid	80-90%	May be difficult to pump
Solid	<80%	Cannot be pumped

Source: SAF (1999)

2.1.2. Bulk Density

It refers to the mass ratio of a sample to the volume it occupies with a unit of kg m^{-3} . The total volume includes particle volume, inter-particle void volume, and internal pore volume. Generally, bulk density was reported in two possible ways; 1) loose bulk density or 2) tap bulk density. Loose bulk density is defined as the density obtained by pouring a sample into a vessel of known volume without any consolidation. Tap bulk density is similar but the vessel is tapped or packed. This tapping procedure accomplished by repeatedly dropping the vessel from a specified height at a constant drop rate until the apparent volume of the sample becomes nearly constant.

Wilhoit *et al.* (1994) reported that the poultry litter bulk density can vary considerably depending on moisture content. They also reported that the bulk density of poultry litter ranges from 470-490 kg m^{-3} .

Pezzi and Rondelli (2002) reported that the bulk density of the four poultry manures ranged from 220 kg m^{-3} to 404 kg m^{-3} . They also found that the litter with the shortest storage time had the lowest bulk density.

Agnew *et al.* (2003) used an air pycnometer to measure the air volume and density of compost. The free air space (FAS) and bulk density of manure compost, municipal solid waste compost, and mixtures of bio-solids and amendment material were measured at various moisture content and compressive loads. They reported that the FAS decreased with loading and increasing moisture content, while the wet bulk density increased with loading and increasing moisture content. They also reported that there was a linear relationship between FAS and bulk density of all the materials tested under load conditions.

2.1.3. Angle of Repose

The angle of repose of manure is the steepest angle of descent or dip relative to the horizontal plane to which a material can be piled without slumping. At this angle, the manure on the slope face is on the verge of sliding. Size, shape, moisture content and orientation of manure particles had an influence on the angle of repose. There are two types of angle of repose i.e., the static angle of repose and dynamic angle of repose. The static angle of repose is the angle of friction taken up by a granular solid to about slide upon itself. The dynamic angle of repose is more important than the static angle of repose as it arises in all cases where the bulk of the material is in motion such as the movement of solids discharging from bins and hoppers.

Malgeryd and Wetterberg (1996) studied the physical properties viz., bulk density, stacking ability or consistency, comminuting resistance, heterogeneity, dry matter content of manures and concluded that bulk density and angle of repose affect the spreading pattern of manure at optimum working width.

Singh R.C and Singh C.D (2013) measured the physical properties of FYM at different depths of manure pit. They found that FYM is a heterogeneous material and physical properties changes with the depth of the manure pit. The angle of repose measured was in the range of 32° to 42°.

2.1.4. Coefficient of Friction

Coefficient of friction is defined as the ratio of the force of friction and the normal force. Friction indicates the resistance to motion of an object or objects in contact with each other. This parameter depends on the surface roughness and how materials slide against each other and thereby considered in the design and evaluation of handling, transporting and spreading equipment.

Hofstee and Huisman (1990) indicated that the coefficient of friction has an impact on the discharge velocity of the particles, discharge angle and discharge position on the spinning disc. They studied the influence of the coefficient of friction on the motion of particles on a disc and along a vane. They utilized a simulation model to predict the impact of friction and reported that it was difficult to demonstrate the effect of friction on the motion of the particles.

Thirion *et al.* (1998) measured the friction coefficient of manure on an inclined plane and noticed that the manure began to slip at an angle of 40° to horizontal plane. The friction coefficient was calculated as $f = \tan(40^\circ) = 0.84$.

Landry *et al.* (2003) determined the amount of friction between different manures viz., pig, poultry, cattle and sheep and on different surface materials viz., bare steel, painted steel, plastic, and plywood. They found that there was no significant difference in the amount of friction between the materials used except for plywood.

Duhovnik *et al.* (2004) studied the material transport of cattle manure along the spinner disc to improve the working principles of spreading it. They reported that manure with moisture contents of 70% and 79% had a coefficient of friction equal to 0.77 and 0.67, respectively. This variation indicated that manure with lower moisture

contents had higher coefficient of friction values. They also reported that the coefficient of friction has an impact on both the length of the path travelled on the disc and the magnitude of radial speed. Higher coefficients of friction yield lower radial speeds. An increase in the coefficient of friction from 0.35 to 0.95 resulted in a 33% longer path and 40% decrease of the radial speed.

2.2. SPREADER CALIBRATION

Calibration is a way of checking or adjusting a manure spreader to ensure manure or nutrient source is being applied uniformly at a desired agronomic rate for a field or group of fields. Calibration of a manure spreader is a simple, easy management tool that can help the farmer use nutrients from animal waste more efficiently.

Parish (2000) conducted field trials on three commercial available spreaders with two different products to determine the application rate and spread pattern using collection trays on a smooth surface. He determined the application rate by converting the average mass collected in the trays in to kg ha^{-1} . He concluded that the spread delivery rates vary in smooth surface than a rough surface.

Mitchell and Tyson (2001) identified the three methods for the calibration of a manure spreader viz., load-area method, trap method and pan method. They reported that the first two methods calculate only application rate and the last method i.e., pan method calculate both the application rate and uniformity with a single pass of the spreader.

Fulton *et al.* (2005) conducted field evaluation trails for four granular fertilizer spreaders to characterize the distribution pattern by adopting the simulated overlapping of plots. They concluded that overlapped pattern generated at calibration showed more application uniformity over non overlapped pattern.

2.3. PULVERIZATION

Pulverisation is the process of disintegration of manure clods resulting from the action of mechanical forces. Clod sizes were measured through sieve analysis and mean clod diameter of the pulverised material was the measure of amount of pulverisation.

Landry *et al.* (2004) used a modified soil sieve shaker with set of sieve sizes of 25.4, 16.4, 8.7, 5.2 and 1.2 mm to evaluate the particle size distribution of different manures. They observed that particle sizes on the top screen (25.4-mm openings) were in the range of 30 to 50 mm. They reported that large manure clods affect the conveying behaviour of manure products.

Fasina (2006) determined the particle size distribution of poultry litter by using a set of sieves with opening of 3.2, 1.6 and 0.8mm and obtained the geometric mean diameter of the particles on each sieve was 0.356, 0.191 and 0.143 mm, respectively.

2.4. EFFECT OF MACHINE AND OPERATIONAL PARAMETERS ON APPLICATION RATE AND PULVERIZATION

Based on the design of equipment, there are many machine and operational parameters effect the application rate and pulverization of different products.

2.4.1. Effect of Forward Speed on Application Rate

EI-Sharabasy *et al.* (2007) conducted field trials on self propelled machine at four different forward speeds of 4,5,6and 7 km h⁻¹, four disc speeds of 350,450,550 and 650 rpm and four gate opening area of 6,12,18 and 24 cm² on seeds and fertilizer. They found that increase in machine forward speed decreased the application rate of paddy and fertilizer. They observed that increase in machine forward speed from 4 to 7 km h⁻¹ decreased the application rate from 72.08 to 50.31 kg ha⁻¹ and from 165.37 to 115.41 kg ha⁻¹ at gate opening of 12 and 18 cm²for paddy and fertilizer, respectively.

Suthakar *et al.* (2008) developed and tested the two wheel trailer manure spreader at three different forward speeds of 1.88, 2.31 and 4.00 km h⁻¹, three chain conveyor speeds of 2.26, 1.88 and 1.51 m min⁻¹ and at three spreader drum speeds of 25.12, 37.68 and 47.10 m min⁻¹. They observed that the application rate of manure was significantly decreased when forward speed increased for all combinations of chain conveyor speeds and spreader drum speeds.

Mohamed Ali Tawfik and Islam M.M. Khater (2009) carried out field experiments to evaluate the twin disc fertilizer spreader at four different forward speeds of 2.5, 4.5, 6.0 and 8.0 km h⁻¹ with set of optimised machine and operational parameters obtained from preliminary experiment. They noticed that there was a decrease in application rate by 57.49 % when forward speed increased from 2.5 to 8.0 km h⁻¹ at 18 cm² gate opening area, effective swath width of 11 m and effective overlap of 42.83 %.

Singh R.C and Singh C.D (2013) developed and tested the tractor trailer cum farmyard manure spreader for application rate at tractor forward speeds of 0.41 ms^{-1} , 0.69 ms^{-1} and 1.12 ms^{-1} with manure delivery rates of 0.46 kg s^{-1} , 1.05 kg s^{-1} , and 2.06 kg s^{-1} and 3.06 kg s^{-1} . They found that manure application rate was decreased from 5.82 to 2.0 tha^{-1} with increase in tractor forward speeds from 0.41 ms^{-1} to 1.12 ms^{-1} at manure delivery rate of 0.46 kg s^{-1} . Similarly manure application rates was decreased from 12.62 to 4.45 t ha^{-1} , 25.75 to 9.09 t ha^{-1} and 36.30 to 12.9 t ha^{-1} with increase in forward speed from 0.41 to 1.12 ms^{-1} at manure delivery rates of 1.05 , 2.06 and 3.06 kg s^{-1} .

2.4.2. Effect of Rotor Speed on Application Rate and Pulverization

Matsou (1961) conducted experiments in a soil bin with four different rotor speeds of 0.26 , 2.88 , 5.50 and 8.65 ms^{-1} to determine the particle size distribution. Significant difference in clod size distribution was observed when the rotor speed increased from 0.26 to 8.63 ms^{-1} .

Destain and Houmy (1990) compared the soil structure created by the rotary cultivator with rotor diameter of 0.16 m at rotor peripheral speeds of 4.2 ms^{-1} & 4.9 ms^{-1} and rotor forward speeds of 1.3 ms^{-1} & 1.8 ms^{-1} . A more homogeneous and greater alteration of soil structure was observed at higher ratio of peripheral to forward speeds due to re-tilling of soil.

Suthakar *et al.* (2008) evaluated the manure spreading attachment to two wheel trailer with three spreader drum speeds of S_1 (25.12 m min^{-1}), S_2 (37.68 m min^{-1}) and S_3 (47.10 m min^{-1}) at a particular forward speed and chain conveyor speed. They found that quantity of manure spread over the field was not dependent on the speed of the spreader drum.

Joseph Reddy (2010) studied the effect of rotor peripheral velocity on soil mean mass diameter (index of pulverization) in the experimental test rig. He observed that increase in rotor peripheral velocity from 3.76 to 5.76 ms^{-1} decreased the soil mean mass diameter for different blade configurations and different number of blades per assembly.

Shiva Bhambota *et al.* (2014) conducted a study to evaluate the pulverization and mixing performance of commercially available three different shape blades at three different rotavator rotor speeds (180 , 215 and 250 rpm) in clay loam soil. They found

that pulverization index decreased for all blade shapes with increase in the rotor speed of rotavator. This was due to the fact that for same forward speed, as rotor speed is increased, the bite length of cut soil decreases which resulted in better pulverization of soil. They observed that lowest pulverization index was observed at 250 rpm (9.53 mm) followed by 215 rpm (9.99 mm) and 180 rpm (13.81 mm) for all types of blade shape.

2.4.3. Effect of Number of Blades per Flange of Rotor on Pulverization

Lee *et al.* (2003) determined the formation of final seed bed condition by measuring the ratio of soil breaking using the following expression.

$$R = \frac{W - w}{W} \times 100$$

Where, R is the percentage of soil breaking, W is the weight of total soil per unit area and w is the weight of soil units with a diameter of 20 mm or more. Investigation on the number of blades per flange viz., one to two, four and six on the percentage of soil breaking was conducted. The rotor with three blades per flange produced highest soil breaking percentage of 24.4 percent. They concluded that highest soil breaking percentage the number of succeeding blades which passed through the undisturbed soil, additional impact and re-tilling of soil.

Joseph Reddy (2010) has conducted experiments under simulated field conditions in the laboratory test rig to determine the effect of number of blades per flange of rotor viz., 2, 4 and 6 on soil mean mass diameter (index of pulverization). He found that decrease in soil mean mass diameter with increase of number of blades per assembly of rotor for different blade configurations and rotor peripheral velocity.

2.4.4. Effect of Blade Shape on Pulverization

Joseph Reddy (2010) investigated the effect of different blade configuration viz., L, C and I on soil mean mass diameter (index of pulverization) in the experimental test rig. He reported that the mass mean diameter of 3.6 mm obtained for L-shape blade was lower than I and C-shape blades at 5.76 ms⁻¹ rotor peripheral velocity, 6 blades per assembly and forward speed of 0.36 ms⁻¹ respectively. He found that in the comparison of lowest mass mean diameter obtained for L-shaped blade, the mass mean diameter of I and C-shaped blades were respectively 5.6 and 10 percent higher than the L-shaped blade.

Shiva Bhambota *et al.* (2014) evaluated the three blade shapes (L, C and J) at three different rotavator rotor speeds for pulverization and mixing performance in clay loam soil. They observed that the average lower pulverization index was in case of J shape blade (10.15 mm) followed by C (11.21 mm) and L shape (11.99 mm). They concluded that J shape blade cut smaller bite length of soil followed by C and L shape blades resulting in smaller mass mean diameter (MMD) of soil clod.

2.4.5 Effect of Feed Control Shutter Area on Application Rate

EI-Sharabasy *et al.* (2007) developed and evaluated the small self propelled machine for spreading seeds and fertilizers at four disc speeds, four machine forward speeds and at four gate opening. They reported that gate opening area was highly affected the spreader distribution effective width and application rate. They found that increase of gate opening area from 6 to 24 cm² increased the effective swath width from 6 to 10 m and increased the application rate of paddy and fertilizer from 27.21 kg h⁻¹ to 319.43 kg h⁻¹ and 29.51 kg h⁻¹ to 344.88 kg h⁻¹ at 4 km h⁻¹ forward speed of the machine.

Singh R.C and Singh C.D (2013) calibrated the tractor trailer cum farmyard manure (FYM) spreader for manure delivery rate and manure application rate by varying the opening width of sliding sheet mechanism provided in the FYM spreader. They reported that with increase on opening width of FYM spreader manure delivery rate and application rate was increased. They observed that at forward speed of 0.41 ms⁻¹, constant opening length of 1.6 ms⁻¹ of sliding sheet mechanism, 540 rpm of manure spreading cylinder and 70 rpm of feeding auger with increase in opening width from 50 mm to 150 mm the manure delivery rate was increased from 1.05 kg s⁻¹ to 3.06 kg s⁻¹ and mean manure application rate increased from 12.6 to 36.6 t ha⁻¹.

2.5. EFFECT OF PARTICLE SIZE ON MANURE DECOMPOSITION

Rynk (1992) explained the various factors affecting the manure decomposition process. He stated that manure particle size affects the aerobic decomposition and the optimum manure particle size of 0.3 to 5 cm produces faster decomposition and yields better results.

Sherman (1999) described the desired characteristics of manure particles for composting process. He reported that smaller manure particles have more surface area, which makes the nutrients and energy more available to the micro organisms. He also reported that particle sizes ranging from 0.003 to 0.05 m in diameter produce faster decomposition.

2.6. OPTIMISATION OF MACHINE AND OPERATIONAL PARAMETERS

Duhovnik *et al.* (2006) have developed a mathematical model for side delivery manure spreading and optimized the spreader rotor rotational speed for distribution range of the manure particles. They reported that the optimum rotor rotational speed of the spreader was between 500 and 600 rpm for better distribution of particles.

EI-Sharabasy *et al.* (2007) developed self propelled machine for broadcasting the seeds and granular fertilizers and optimised the machine and operational parameters of based on coefficient of variation (CV) and coefficient of uniformity (CU) values. They reported that machine achieved the lower coefficient of variation (CV) of 16.28 and 19.16 % and higher coefficient of uniformity (CU) of 83.72 and 80.84 % at disc speeds of 6.12 and 7.48 ms⁻¹ and gate opening area of 12 and 18 cm² for spreading paddy and fertilizer, respectively.

Suthakar *et al.* (2008) statistically analysed the performance of manure spreading attachment to two wheel trailer using technique of variance (ANOVA) to assess the effect of levels of variables, namely, forward speed (F), chain conveyor speed (C) and spreader speed (S) on application rate. They reported that from ANOVA analysis, the spreader drum speed did not influence the application rate while spreader forward speed and chain conveyor speed had influence on the application rate. They optimised the operational variables of spreader machine based on the desired application rate. They observed that the desired application rate of 12.2 t ha⁻¹ was obtained at forward speed of 2.31 km h⁻¹, chain conveyor speed of 1.51 m min⁻¹, any spreader drum speed and the effective swath width of 1.20 m.

Mohamed Ali Tawfik and Islam M.M. Khater (2009) evaluated the twin disc fertiliser spreader using granular ammonium nitrate on sugar beet crop. They conducted preliminary experiment and optimised the operating parameters affecting the performance of twin disc fertiliser spreader based on coefficient of variation (CV), coefficient of uniformity (CU) and coefficient of correlation values (CC). They reported that the fertilizer spreader achieved the lowest value of CV, highest value of CU and CC at spinner speed of 52.3 rad s⁻¹ (500 rpm), backward angle of -15°, spinner angle of zero degree and gate opening of 18 cm² using four C-shaped blades and spinner height of 50 cm.

Joseph Reddy (2010) carried out experiments in a test rig with the different combinations of blade configurations, number of blades per assembly, rotor peripheral speed and forward speed. He optimised the different combinations based on minimum soil mean mass diameter and soil clod distribution for the development of rotary strip till drill. He reported that minimum soil mean mass diameter of 3.6 mm was obtained for L-shape blade at 5.76 ms^{-1} rotor peripheral velocity, 6 blades per assembly and forward speed of 0.36 ms^{-1} .

2.7. COST ECONOMICS OF MANURE SPREADER

Singh R.C and Singh C.D (2013) developed tractor trailer cum manure spreader and calculated the cost of operation of manure spreading. They observed that operational cost of developed farmyard manure spreader and conventional tractor trailer system were Rs.124 and Rs.280 per hour, when both the machines were used for transportation and manure spreading for 500 h per year in 6 years of life span. They reported that the developed machine saved Rs.156 h^{-1} over the conventional tractor trailer used for manure spreading and transport work.

Chapter V

SUMMARY AND CONCLUSIONS

Application of FYM ameliorates the soil physical, chemical and biological properties and act as a cheap source of nutrients. In India, the manure application process is very laborious, uneconomical and time consuming process. The problem faced in the application of manure during the indigenous method is the non uniform application rate and non disintegration of large manure clumps. It was also observed that during manual application of manure to the fields, there were many large manure clods were left un-decomposed. This might be due to the conditions that were not favored for piled manure under which it is permitted to decay. Pulverization of large un-decomposed FYM clods to 0 to 40 mm size encourages the faster decomposition when hits the lands due to the more surface area exposed for the attack of micro organisms present in the soil, environment and FYM. In an attempt, for solution to problems with the indigenous method of manure application and to pulverize the large un-decomposed manure clods, an implement was developed at Regional Agricultural Research Station (RARS), Nandyal to pulverize and spread the solid organic manure simultaneously in the field, which is compatible to the tractor operated tipping trailer.

To meet the desired agronomic FYM application rates in pulverized form, the physical properties of FYM and the behavior of the machine at different components and operational settings affecting the performance of the machine was studied under prescribed levels. Hence, a study was carried out on the performance evaluation of the FYM pulverizer cum spreader. The machine parameters with levels viz., feed control shutter opening (half open and full open), number of blades per flange of rotor (2, 3, and 6) and operational parameters viz., spreader peripheral velocity (4.72 ms^{-1} , 6.92 ms^{-1} , 7.86 ms^{-1}) spreader forward speed of (2 Km h^{-1} , 3 Km h^{-1} and 5 Km h^{-1}) were selected to study the effect on bulk density, clod size distribution and FYM application rate.

5.1. EFFECT OF SELECTED VARIABLES ON BULK DENSITY

1. Bulk density decreased with increase in peripheral velocity and number of blades per flange of rotor at half and full shutter opening.
2. The lowest bulk density of 0.510 g cm^{-3} and 0.515 g cm^{-3} was obtained at rotor peripheral velocity of 7.86 ms^{-1} (V_3) and 3 number of blades per flange (N_2) at half and full shutter opening.
3. There is no decrease in bulk density with increase of number of blades per flange from 3 to 6 at 7.86 ms^{-1} peripheral velocity for full and half shutter opening.
4. The bulk density obtained at full shutter opening was higher when compared to the bulk density obtained at half shutter opening.

5.2. EFFECT OF SELECTED VARIABLES ON CLOD SIZE DISTRIBUTION

1. Percentage of minimum clod size distribution ranging from 0 to 40 mm increased with increase in peripheral velocity and number of blades at half and full shutter opening.
2. The highest percentage of 78.28 and 66.55 minimum clod size distribution ranging from 0 to 40 mm was obtained at 7.86 ms^{-1} peripheral velocity and 3 number of blades at half and full shutter opening area.
3. There is decrease in 0 to 40 mm clod size distribution with increase of number of blades per flange from 3 to 6 at 7.86 ms^{-1} peripheral velocity.
4. The clod size distribution obtained at full shutter opening was higher when compared to the clod size distribution obtained at half shutter opening.

5.3. EFFECT OF SELECTED VARIABLES ON APPLICATION RATE

1. The highest application rate of 5.8 t ha^{-1} and 12.6 t ha^{-1} was obtained at forward speed of 3 km h^{-1} (F_2), peripheral velocity of 7.86 ms^{-1} (V_3) and 3 no of blades per flange of rotor at full and half shutter opening.

2. The application rate decreased at 7.86 ms^{-1} (V_3) peripheral velocity and 6 number of blades per flange for full and half shutter opening.
3. The application rate decreased with increase of forward speed from 2 km h^{-1} to 5 km h^{-1} at particular peripheral velocity with specified number of blades.

5.4 OPTIMIZED VARIABLES TOWARDS THE DEVELOPMENT OF PROTOTYPE PULVERIZER CUM SPREADER

From the results, one combination each that resulted the minimum bulk density, maximum percentage of minimum clod size distribution in the range 0 to 40 mm and optimal discharge rate were selected at half and full opening of shutter area. The following optimized parameters were considered for the fabrication of the prototype pulverizer cum spreader.

Optimized parameters	Half opening size	Full opening size
Peripheral velocity, ms^{-1}	- 7.86 (V_3)	7.86 (V_3)
Forward speed, km h^{-1}	- 3 (F_2)	3 (F_2)
Number of blades per flange, No`s	- 3 (N_2)	3 (N_2)

5.5. FIELD EVALUATION OF THE PROTOTYPE FYM PULVERIZER CUM SPREADER

The tractor operated prototype pulverizer cum spreader was developed and evaluated for field performance with the best optimized variables derived from the experimental trails. The bulk density, clod size distribution and discharge rate were observed at half and full shutter opening area. The bulk density, clod size distribution and application rate was observed as 0.512 g cm^{-3} & 0.521 g cm^{-3} , 75.99% & 64.45% and 5.9 t ha^{-1} & 12.5 t ha^{-1} at half and full shutter opening area respectively.

The operational cost of developed farmyard manure spreader was Rs.724 per hour, when the machine was used for dry FYM Pulverizing and spreading operation.

Chapter VI

SUGGESTIONS FOR FUTURE WORK

- 1) Intensive field evaluation of the unit has to be done for dry condition.
- 2) Optimum machine and operational parameters are to be developed for FYM pulverizer cum spreader under wet condition.