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Study the Physical Properties of Fertilizers and Plant Basin Parameters to Design the Tractor Operated Round Basin Maker cum Fertilizer Applicator for Orchard Crop

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The physical form of fertilizer production is of extremely importance, both agronomically and in regard to satisfactory handling, transport, storage, and finally application to the field. The improvement of equipment for handling, storage, and application of granular fertilizer require a proper understanding of material properties and flow behavior. The most common problems encountered in fertilizers were caking, poor flow ability, segregation, dustiness and excessive hygroscopicity due to differences of physical properties. The physical properties such as moisture content, angle of repose and bulk density as important in designing the hopper and metering roller of fertilizer plays an important role in the storage, transport and application of fertilizer. The urea, Ammonium phosphate Sulphate, complex fertilizers and fertilizer ratio (10 26 26) per one orchard tree should be applied yearly trice based on crop requirement. The angle of repose value ranges 28° -37° the hopper angle was decided. For that, to flow the fertilizer freely from the hopper, the inclined angle of the hopper should be greater than 40° respectively. The lowest bulk density and tapped density observed 0.648 kg cm^{-3} and 0.708 kg cm^{-3} respectively. Coefficient friction for galvanized Iron (GI) material is very high So, based on the obtained results, a fertilizer applicator for orchard crops has been designed. The basin diameter of orchard palm varies from 1500 mm to 1750 mm the mean of 1650 mm. The root zone depth of orchard crop varies from 150 to 180 mm at radius of 1800 mm from the base of palm. The mean 171.66 mm hence depth of operation of machine was selected as 150 mm such that the machine does not interfere with root zone of orchard trees.

Keywords: Orchard crops; fertilizers applicator; physical properties; angle of repose; density; friction; plant parameters; basin parameters.

1. INTRODUCTION

“In India, area under horticulture crops raised by 2.6 percent per annum” [1]. “Fruits and vegetables account for nearly 90 % of total horticulture production in the country. The major challenges in production enough to meet the growing demand under changing climate conditions, falling agricultural land, water, other natural resources and labour” [2].

“The newly planted young fruit plants, being very tender need lot of care and attention for their better survival and growth. Irrigation and nutritional management are the dominant factors in orchard farming. Application of irrigation and fertilizers on orchard tree is a fairly tremendous process. Fertilizer is generally applied manually in circular basins from base of the stem palm at a depth of 10 cm. The physical form in which a fertilizer is produced is of considerable importance, both agronomically and in regard to satisfactory handling, transport, storage, and finally application to the field. The fertilizer rates to be applied first 2-3 years of orchards 100 grams of N, 100 grams of P and 100 grams of K in some areas formers used single super phosphate 14-35-35 and urea are used yearly trice” [3] “The physical property of the fertilizer is having importance in handling, storage and application to the field. The most common problems encountered in fertilizers were caking, poor flow ability, segregation, dustiness and excessive hygroscopicity due to differences in physical properties. The physical and engineering properties such as moisture content, angle of repose and bulk density as important in designing the hopper and metering roller of fertilizer plays an important role in the storage, transport and application of fertilizer [4]. This study physical and engineering properties of fertilizer helps in the usage of low amount of fertilizer, which means the fertilizer was applied in the right way with the optimal amount and at the correct time [5]. The study of moisture content of the fertilizer helps to decrease the cacking tendency of the fertilizer in hopper and clogging of the equipment so, study the physical properties of fertilizer very necessary for designing tractor operated round basin making cum fertilizer applicator [6]. Many agricultural fertilizers come in the form of bulk granular materials. Improving handling, storage, and application equipment for granular fertilizers requires engineering design and analysis. The present study sought to determine properties for granular fertilizers through measurement and experimentation” (YSR HU glance, 2022) [7].

"Good physical condition, which is relatively easy for the customer to evaluate by simple observation, ensures him of easier, faster, more uniform and less expensive application to the field. Also, in the various handling, transport, and storage steps that usually are involved between production and final use of fertilizers, it is essential that physical properties be such that the material remains free flowing (non caking), that it be relatively non dusty, and that it with stand a reasonable amount of exposure to normal atmospheric humidity" (YSR HU glance, 2022).

2. MATERIALS AND METHODS

According to the package of practices of Dr YSR Horticultural University, Andhra Pradesh. The urea, Ammonium phosphate Sulphate, complex fertilizers and fertilizer ratio (10 26 26) per one orchard tree should be applied yearly trice based on crop requirement. The fertilizer physical properties viz., bulk density, tapped density, angle of repose, coefficient of friction, and flow ability are required for development of fertilizer applicator different types of fertilizer depicted on Fig.1.

2.1 Angle of Repose

"The angle of repose was the significant parameter to determine the characteristics of granular fertilizer materials with their storage surface and its values were used in the design of the hopper. Angle of repose of fertilizers was measured by filling sample into a cylinder by keeping it horizontal and then cylinder was raised slowly allowing the fertilizer to flow out and form a heap in the form of cone. The angle of repose was determined by the following equation" (Hamzah and Omar 2018). The diameter of the conical shaped heap and its height formed on the plate were measured. Higher values of angle of repose were showing free flow ability compared to lower values (Fig. 2).

$$\text{Angle of repose } (\theta) = \tan^{-1}\left(\frac{2h}{d}\right)$$

Where,

θ = Angle of repose, (deg)
H = Height of heap, cm,
d = radius of the heap, cm

1) APS 2) Urea 3) Complex fertilizer and 4) NPK Mixture

Fig. 1. Four different types of fertilisers for measurement the physical properties

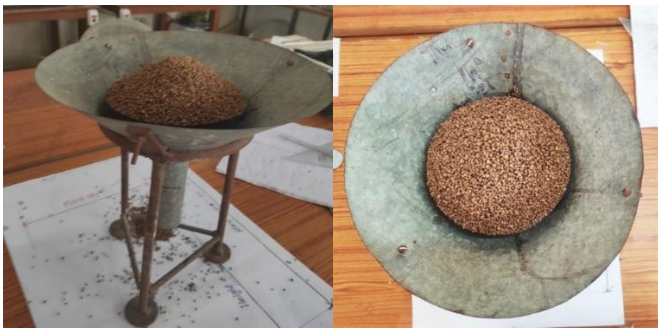

Fig. 2. Measurement the angle of repose for granular fertilizers

2.2 Bulk Density

The bulk density defined as the mass per volume of a bulk fertilizer, including void space in a container. The bulk density of fertilizer helps in deciding hopper dimensions of fertilizer applicator and estimated by measuring the known weight of fertilizer samples in a container with certain volume. Bulk density of fertilizers decides the requirements of the volume of the hopper [8-13]. The bulk density of fertilizer sample was calculated as (Basavaraj and Jayan 2020):

$$\rho = \frac{W}{V}$$

where,

ρ = bulk density, g m^{-3}
W = weight of fertilizer, g,
V = volume of container, m^3

Fig. 3. Measurement the bulk density for granular fertilizers

2.3 Tapped Density

Tapped density represents the maximum density to which a material might be reduced by vibration during operation. The test sample is filled into metal box and the box is dropped 10 cm off on floor several times. The void created by dropping is refilled and the dropping is continued until compaction is complete. The box with test sample then is weighed, and the weight of the empty box is subtracted to give the weight of the test sample. The tapped density is calculated as [4,3].

$$D_t = \frac{W1 - W2}{V}$$

Where,

D_t = Tapped density, g /m^3

W_1

W_1= Weight of fertilizer with box, g,
W_2 = Weight of box, g,
V = Volume of box, m^3

2.4 Flow Ability

"It is an important parameter where it is directly related to the flow rate, handling, metering and deposition of fertilizer. The flow ability of fertilizer is reduced due to its cacking tendency, moisture content, and segregation of fertilizer particles. The fertilizer flow rate was measured by considering 1.5 kg of fertilizer sample placed in a standard funnel with a closed bottom. It has an aperture of 20 mm diameter at its base. Then the gap was opened and the time consumed for the flow of 1.5 kg of fertilizer from the funnel was measured" [5].

2.5 Coefficient of Friction

It is the degree of friction developed between a material and the storage surface. A higher degree of friction can result in longer contact with the surface. It is useful in the design of the hopper where the fertilizer slide over the hopper sheet. Coefficient of static friction of fertilizers is measured for different metal sheets i.e., (GI, iron and aluminium). The produce was replicated three times for each surface material. The coefficient of static friction was calculated as the tangent of angle of inclination (α) and is given by the following equation [6].

$$\mu = \tan(\alpha)$$

where,

μ = Coefficient of friction,
F = Frictional force (force applied), kg ,
N = Normal force (weight of the fertilizer), kg.

Fig. 4. Measurement the coefficient of friction for granular fertilizers

2.6 Plant Parameters

Major crop parameters such as root depth, root length from the stem, basin diameter, and basin depth and stem diameter were measured and recorded. The root zone depth was studied at the time of basin making and fertilizer application for orchard crops. The plant parameters are important to design tractor operated round basin making cum fertilizer applicator. One to ten years orchards crops was selected for the study because of more nutritional and irrigation requirement initial 10 years orchard establishment. Plant parameter such as Root Depth, Basin diameter and basin depth are taken from randomly selected 25 trees in different crops at different age groups.

3. RESULTS AND DISCUSSION

3.1 Angle of Repose

The angle of repose is the important parameter which influences the design of hopper for the flow ability of fertilizer without any clogging. The angle of repose of urea, ammonium phosphate sulphate, complex fertilizers and fertilizer ratio (10 26 26) were found out. Based on the values (Table 1) of angle of repose of fertilizer combination the hopper angle was determinedthe So, to flow the fertilizer freely from the hopper, the inclines angle of the hopper should be greater than 40° [3].

3.2 Bulk Density

The bulk density of fertilizers was determined as explained in material and method section. The bulk density is found to be ranging between 0.647 g cm^{-3} to 0.864 g cm^{-3} it was listen in (Table 2). The bulk density of urea was less compared to other fertilizers as it is having lesser weight for a given volume of beaker.

3.3 Tapped Density

Tapped density of urea, urea, Ammonium phosphate Sulphate, complex fertilizers and fertilizer ratio (10 26 26) were observed values, respectively, the difference between density and normal density as shown in Table 2. The tapped density values have been considered to design the hopper and metering roller fertilizer applicator. The values obtained for tapped density are comparable to [3].

3.4 Flowability

The flow ability of urea, Ammonium phosphate Sulphate, complex fertilizers and fertilizer ratio (10 26 26) was determined above section. The average time taken to flow 1.5 kg of from the funnel bottom was average 4-6 seconds. It was observed that the fertilizer was flowing freely without any segregation in the funnel.

3.5 Coefficient of Kinetic Friction

The coefficient of kinetic friction of fertilizers (viz., urea, Ammonium Phosphate, potash complex fertilizers and fertilizer combination (10 26 26)) was determined for GI sheet material as it is used for designing hopper. The results were mentioned in below Table. The coefficient of friction for urea was observed low compared to other fertilizers. The coefficient of friction is influenced to a minor extent by the velocity relative to the friction surface layer. The results dedicated at Fig.5.

Table 1. Angle of repose for different fertilizers

Sl.No.	Type of Fertilizers	Angle of Repose
1	Urea	37
2	Ammonium phosphate Sulphate,	28
3	complex fertilizers	32
4	Fertilizer ratio NPK (10 26 26)	32

Table 2. Density and tapped density for different fertilizers

Sl.No.	Type of Fertilizers	Density g cm^{-3}	Tapped Density g cm^{-3}	Difference %
1	Urea	0.647	0.708	8.66
2	Ammonium phosphate Sulphate	0.848	0.937	9.52
3	complex fertilizers	0.859	0.914	6.09
4	fertilizer ratio (10 26 26)	0.864	0.954	9.35

Table 3. Coefficient of friction values for different fertilizers

Type of Fertilizers	Different Types of materials		
	MS	GI	Aluminium
Urea	1.22	1.31	1.25
Ammonium phosphate Sulphate	1.23	1.23	1.24
complex fertilizers	1.17	1.27	1.17
fertilizer ratio (10 26 26)	1.23	1.20	1.17
Mean	1.21	**1.25**	1.21
Standard Deviation	0.030	0.047	0.043
CV	2.51	3.75	3.6

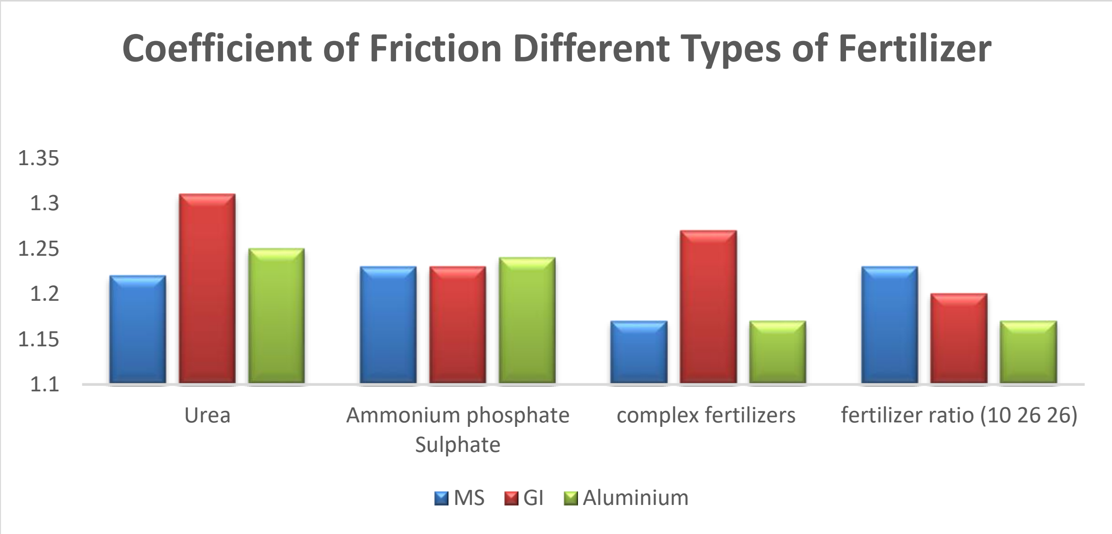

Fig. 5 Coefficient of friction for granular fertilizers

Table 4. Plant and basin parameters

S. No	Plant and basin parameters	Mango	Guava	Orange	Mean
1.	Root zone depth (mm)	180	160	175	**171.66**
2.	Basin diameter (mm)	1700	1500	1650	**1650**
3.	Basin depth (mm)	150	170	160	**160**

3.6 Plant and Basin Parameters

The plant parameters such as basin diameter around the palm, depth of basin making and root zone depth of orchard pal were find out at the time of basin making and fertilizer application. The data obtained from experiments was statistically analysed. The basin diameter of orchard palm varies from 1500 mm to 1750 mm the mean of 1650 mm depicted in Table 4. The basin diameter varied with verity and age of orchard palms. The root zone depth of orchard crop varies from 150 to 180 at radius of 1.8m from the base of palm. The mean 171.66 mm hence depth of operation of machine was selected as 150 mm such that the machine does not interfere with root zone of orchard trees.

4. CONCLUSION

The physical properties of selected granular fertilizers were studied for design of fertilizer applicator for orchard crop. The size of fertilizers was significantly different. The angle of repose value ranges 28° -37° the hopper angle was decided. So, to flow the fertilizer freely from the hopper, the inclines angle of the hopper should be greater than 40° respectively. The lowest bulk density and tapped density observed 0.648 kg cm^{-3} and 0.708 respectively. Coefficient friction for GI material is very high So, based on obtained results design the fertilizer applicator for orchard crops. The basin diameter of orchard palm varies from 1500 mm to 1750 mm the mean of 1650 mm. The root zone depth of orchard crop varies from 150 to 180 mm at radius of 1800 mm from the base of palm. The mean 171.66 mm hence depth of operation of machine was selected as 150 mm such that the machine does not interfere with root zone of orchard trees.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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