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Study of physical properties of manure that influence the development of FYM pulverizer cum basal applicator

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Abstract

As the population of our country is increasing day by day, there is a need to supply food to each and every individual. It can be done by increasing the productivity of the crop by supplying enough nutrients to soil with organic manures. Though the chemical fertilizers increase the productivity, it deteriorates the soil qualities and causes imbalance in chemical equilibrium. So application of organic manures is the only way out. Farmers usually follow manual manure application practices which involve lot of drudgery for its field application. Physical properties of the manure affected the manure discharge rate through the blower. Denser manure gets deposited at the corners and on the other hand less dense manure creates drift due to atmospheric wind. A study was conducted to determine the physical properties of manure to develop a machine for Farm Yard Manure (FYM) pulverizer cum applicator. Bulk density of the dried manure was found out as 195, 492 and 520 kg m^{-3} for cow dung, goat faecal pellets and neem cake respectively. Sun dried manure was preferred and recommended for clump free pulverization. Tapped density of the dried manure was found out as 308, 668 and 748 kg m^{-3} for cow dung, goat faecal pellets and neem cake, respectively. Angle of repose was found out as 43±0.1, 37±0.1 and 38±0.1 deg for cow dung, goat faecal pellets and neem cake. Optimum angle of repose of pulverized manure helped in easy flow ability, suction and conveying of manure. Results from the study indicated the need of developing an air tight casing for the pulverizer cum blower to prevent the effect of wind. Coefficient of friction and degree of pulverization also played an important role in optimizing the blower speed to dissipate the powdered manure directly to the soil.

Keywords: Basal applicator, FYM applicator, Physical properties of Manure, Pulverization.

Introduction

Manures *viz.,* Farm Yard Manure (FYM), vermicompost, edible oil cake are important sources which provide nutrients that could reduce the cost of chemical fertilizer and improvethe crop growth and performance. A well-managed manure is a valuable resource in providing nutrients for crop production. Use of FYM and other organic manure is the way out to overcome the problems of soil degradation, loss of fertility and soil health (Elizabeth et al., 2012). A larger portion of nitrogen is made available, as and when the FYM decomposes. Application of FYM improves soil fertility, therefore there is a wide scope for its application. Also, the application of recommended doses of manures at the proper time would stabilize the soil fertility status and hence improve soil productivity.

Manure gets decomposed as soon as it is applied on the soil by the action of microorganisms present in the soil (POP, 2016). To speed up the decomposition process, it is necessary to break up the manure clods and make more surface area exposed to the microorganisms. Lesser the manure clod size, more the surface area exposed for the attack of microorganisms (James et al., 2000). Also, scientific

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studies revealed that the fine powder is easily absorbed by the soil, easy to handle due to decreased volume and more nutrient concentration in less weight (Jotautiene et al., 2017). Problems like drift and drudgery caused in manual manure application results in health problems. Improper and inaccurate broadcasting causes abnormal and non-homogeneous soil fertility which is against the purpose of sustainable agriculture. Hence, there is a need of using innovative manure pulverizer and applicator machines in the farm (Choudhary et al., 2016). A study was hence conducted to determine the physical properties of manure towards the development of pulverization cum applicator unit (FYM basal applicator).

Materials and methods

Manure requirements of different soils

As agriculture is facing the problems of soil degradation, loss of fertility and soil health, the use of farm manure and organic materials isapt solution. A larger portion of nitrogen is made available when the manure decomposes. Availability of potassium and phosphorus from manure is similar to that of inorganic fertilizers. Application of manure improves soil fertility, hence there is wide scope to its application.The application rate of various manure was observed for different crops according to the agronomic conditions of Kerala state. The components of the proposed machine were developed to suit the various dosages of manure without much variation in the distribution efficiency.

Table 1. Nutritional composition (percentage) of manures (Pabitra, 2011)

Type of manure	N_2	P_2O_5	K_2O
Cow dung	1.09	0.82	0.70
Neem cake	5.00	1.10	1.50
Goat faecal pellets	3.00	1.00	2.00

Physical properties of manure

Physical properties of manure directly affect the pulverization capacity, design of blower and manure dissipation (Sahey et al., 2001). Less dense nature of the manure results in decreased pulverization capacity and application rate and on the other hand as the moisture content increases it retards the pulverization process. The important physical properties of pulverized manure are moisture content, bulk density, angle of repose, terminal velocity and coefficient of friction. Physical properties of the manure mainly influence the design of feeding chute between pulverizer and blower, blower inlet design, and flexible discharge outlets. The detailed procedure for measurement of physical properties of pulverized manure is described below.

Bulk density

Bulk density affects the handling of manure inside the machine. The bulk density of a powder is the ratio of the mass of an untapped powder sample and its volume including inter particulate void volume. The bulk density is expressed in kilogram per cubic metre. A 50 ml empty cylinder (w_1) was weighed and the volume of the cylinder was measured. The manure sample was allowed to flow freely into the measuring cylinder until it overflowed. The excess powder was scraped carefully from the top of the cylinder. The cylinder and the sample were then weighed (w_2). This procedure was repeated for 3-5 replications. The bulk density was calculated as the weight of sample by the volume of cylinder and given by the expression,

$$\text{Bulk density, } D_b = \frac{W_2 - W_1}{V}$$

…(Landry et al., 2004)

where, W_1 = weight of the cylinder (g)

W_2 = weight of the cylinder and sample (g)

V = volume of the cylinder (cm^3) = $\frac{\pi}{4} \times d^2 \times h$

h = height of the cylinder, cm

Tapped density

Tapped density is an increased bulk density attained after mechanically tapping a container containing the powder sample. It is the ratio of the mass of powder to the volume occupied by powder after it has been tapped for a defined period of time. Tapped density of a powder represents its random dense packing. The initial weight of the cylinder(w_1) was determined. The cylinder was then filled with manure and tapped continuously to get a constant volume. Measure the final height of cylinder and calculate the tapped volume of the cylinder. Tapped density is given by the expression,

$$\text{Tapped density, } D_t = \frac{W_1 - W_2}{W_2}$$

where, W_2 = weight of the container & sample (g)
W_1 = weight of the container (g)
V = volume of the container (cm^3)

Moisture content
The moisture content of manure was determined by using hot air-oven method. 5g of sample was weighed and taken in the tare porcelain dish (W_1). The sample was placed in the oven at 105±2 °C for 24 h, and then it was cooled in the desiccators. Oven dried sample weight was noted (W_2). Moisture content was measured in dry basis and is determined using the equation,

$$\text{Moisture content (\%)} = \frac{W_1 - W_2}{W_2} \times 100$$

…(Sahay and Singh, 2001)

where, W_1 – initial weight of the sample (g)
W_2 – final weight of the sample (g)

Angle of repose
Angle of repose is the angle between base and slope of the cone formed on free vertical fall of the mixture to the horizontal plane. It is the ability of the product to flow and each product has its own angle of repose. The size, shape, moisture content and orientation of particles influence the angle of repose. It was measured using an apparatus which consisted of a metal conical funnel with an open bottom, fixed on a metal stand and below an iron disc on which various diameters were marked. Sample was filled in the funnel and allowed to heap freely on iron disc from open bottom. The height and diameter of the cone were measured. Angle of repose was determined using the equation,

Angle of repose, è = $\tan^{-1}$ (2h/d)

…(Sahay and Singh, 2001)

where, è = angle of repose in degree
h = height of the cone, cm
d = diameter of the plate, cm

Angle of repose of the pulverized manure plays an important role in deciding the flow angle while fabricating the conveying chamber for pulverizer cum applicator. Higher value of angle of repose results in more free flowing of powdered manure whereas lesser value of angle of repose results in clogging.

Coefficient of friction
Coefficient of friction apparatus consists of a horizontal plane and a bottomless open container and a pan. Known weights of manure were taken in the container. The weights were added in the pan and the instant at which the pan weight exceeds the manure; the container began to slide. The coefficient of friction measures both external and internal contact of manure with the horizontal plane. Hence, coefficient of friction is more important for sliding the manure as compared to angle of friction (Singh and Singh, 2014). Following equation is used for determination of coefficient of friction as:

$$\mu = \frac{F}{N}$$

…(Singh and Singh, 2014)

where, μ = coefficient of friction,
F = frictional force (force applied), kg and
N = normal force, kg (weight of the manure)

Degree of pulverization
The finer the particles will be easier to decompose in soil (James et al., 2000). Pulverization performance is evaluated by calculating mean width diameter (MWD) of the manure samples. By varying the input engine rpm and interchanging the pulleys, the blade rotation increases which increases its pulverization capacity.

Degree of pulverization was calculated by performing sieve analysis with standard sieves in the mechanical sieve shaker. The sieves used for fine sieve analysis were 2.0 mm, 1.0 mm, 600µm, 425µm, 300µm, 212µm, 150µm and 75 µmIS sieves. Weight of sample retained on each sieve was noted.

Degree of pulverization is measured by,

$$MWD = \sum_{i=1}^{n} \frac{W_i}{W} D_i$$

where, W_i = weight of the soil gathered in each grade, gm

W = total weight of the soil sieved, gm

D_i = mean diameter referred to each grade, mm

n = number of grades

Statistical analysis

Triplicate analysis of the data was done using IBM SPSS (International business machines-statistical package for social sciences) software. Analysis of variance was performed by the ANOVA procedure. A level of significance of $p<0.05$ was used throughout the analysis.

Results and discussion

Physical properties of manure effect the pulverization capacity as well as application rate. Bulk density, tapped density, moisture content, angle of repose, coefficient of friction and degree of pulverization were determined and results are described below.

Bulk density

Bulk density of manure was found out as 195 kg m^{-3} for cow dung, 492 kg m^{-3}for goat faecal pellets, and 520 kg m^{-3} for neem cake. Bulk density of cow dung was found to be very less compared to goat faecal pellets and neem cake. For a given volume of the cylinder, less weight of the manure occupies more volume resulting in a lesser bulk density. Also, it effects the application rate of manure for a given time period.

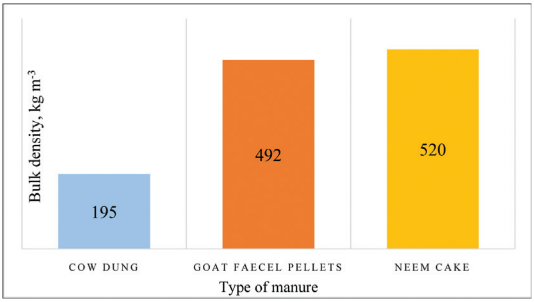

Figure 1. Bulk density of cow dung, goat faecal pellets and neem cake

Statistical analysis of the data was done using IBM SPSS (International Business Machines-Statistical Package for Social Sciences) software for the results obtained for bulk density. The analysis of variance for different manure types are as shown below (Table 2).

Bulk density had a significant effect on pulverizing capacity at 5 % level of significance ($p\leq 0.05$) and having the R-squared value of 0.99.

Tapped density

Tapped density of manure was determined and found out as 308 kg m^{-3} for cow dung, 668 kg

Table 2. Analysis of variance on Bulk density

Source	Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	0.19[a]	2	0.09	1504.77	0.0
Intercept	1.45	1	1.45	22491.27	0.0
VARIETY	0.19	2	0.09	1504.77	0.0
Error	0.00	6	6.46×10^{-5}		
Total	1.64	9			
Corrected Total	0.19	8			

a. R Squared = .998 (Adjusted R Squared = .997)

Grand Mean

Dependent Variable : Bulk density

Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
0.402	0.003	0.395	0.409

Table 3. Analysis of variance on Tapped density

Source	Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	0.32[a]	2	0.16	115.82	0.0
Intercept	2.97	1	2.97	2096.48	0.0
VARIETY	0.32	2	0.16	115.82	0.0
Error	0.00	6	0.00		
Total	3.31	9			
Corrected Total	0.33	8			

a. R Squared = .975 (Adjusted R Squared = .966)

Grand Mean

Dependent Variable: Tapped density

		95% Confidence Interval	
Mean	Std. Error	Lower Bound	Upper Bound
0.562	0.024	0.503	0.622

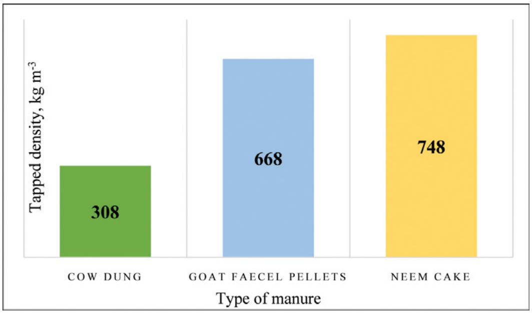

Figure 2. Tapped density of cow dung, goat faecal pellets and neem cake

$m^{-3}$for goat faecal pellets, and 748 kg m^{-3} for neem cake. Manure becomes dense inside the chute because of continuous deposition. Hence tapped density was determined as a measure of dense nature of manure.

Statistical analysis of the data was done using IBM SPSS and the analysis of variance (Table. 3) shown that the effect of tapped density on pulverizing capacity and application rate had significant at 5 % level of significance ($p \leq 0.05$) and the R-squared value was 0.97.

Moisture content

The moisture content of manures *viz*., cow dung, goat faecal pellets and neem cake were measured by oven dry method and were statistically analyzed. Increase in the moisture content of manure causes decrease in the efficiency due to adhesive nature of manure. When moisture content of manure exceeded 25 per cent, wet lumps were formed affecting the pulverizer capacity. Cohesive nature of manure turns into adhesive nature and sticks to side walls of pulverizer drum due to rotation of pulverizing blade. Statistical analysis of the data was doneusing IBM SPSS. it was noted that the effect of moisture content on pulverizing capacity and application rate had shown significant at 5 % level of significance ($p \leq 0.05$) and the R-squared value was 0.94.

Table 4. Analysis of variance table on Moisture content

Source	Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	38.22[a]	2	19.11	21.5	0.0
Intercept	2844.44	1	2844.44	3200.0	0.0
VARIETY	38.22	2	19.11	21.5	0.0
Error	5.33	6	0.88		
Total	2888.000	9			
Corrected Total	43.556	8			

a. R Squared = .878 (Adjusted R Squared = .837)

Dependent Variable: Moisture content

		95% Confidence Interval	
Mean	Std. Error	Lower Bound	Upper Bound
17.778	0.314	17.009	18.547

The average values of moisture content were found to be 19.04 per cent for cow dung, 19.04 per cent for goat faecal pellets and 21.03 per cent for neem cake respectively. When the moisture content is more than 25 per cent, the cohesive and adhesive nature of manure effects the suction and discharge through the blower. Wet manure showed sticky nature with impeller and wall of blower casing, which ultimately clogged the inlet and outlets. Sundried manure exhibited good performance compared to shade stored manure.

Angle of repose

Angle of repose plays an important role in design and development of hoppers and chutes and has considerable effect on the sliding of manure. Pulverized cow dung gets accumulated in the hopper since it occupies more volume with less weight, whereas goat faecal pellets and neem cake gets dissipated as quickly as possible because of its less volume to weight ratio. Angle of repose was found out to be 43±0.1 deg for cow dung, 37±0.1 deg for goat faecal pellets and 38±0.1 deg for neem cake. Since the pulverized mixture was finer, angle of repose increased with the decrease in particle size of powder. These results were used in the design and development of hopper, casing and outlets for application unit.

Coefficient of friction

The coefficient of friction of pulverized manure (*viz*., cow dung, goat faecal pellets and neem cake) for GI sheet, mild steel and aluminum was determined and results were presented in Table 5.

Table 5. Coefficient of friction of pulverized manure

Material surface	Cow dung	Goat faecal pellets	Neem cake
	Mean ± SD		
GI sheet	0.478 ± 0.01	0.458 ± 0.02	0.453 ± 0.01
Mild steel	0.525 ± 0.02	0.502 ± 0.01	0.494 ± 0.01
Aluminum	0.540 ± 0.01	0.546 ± 0.01	0.552 ± 0.02

Forward motion and vibrationof the machine during field operation helps in keeping pulverized manure in motion, not allowing it to reach its maximum permissible angle of repose. Increase in the moisture content of manure makes it sticky and it gets clogged in the working unit. GI sheet was selected considering strength, cost and fabrication easiness compared with other metals.

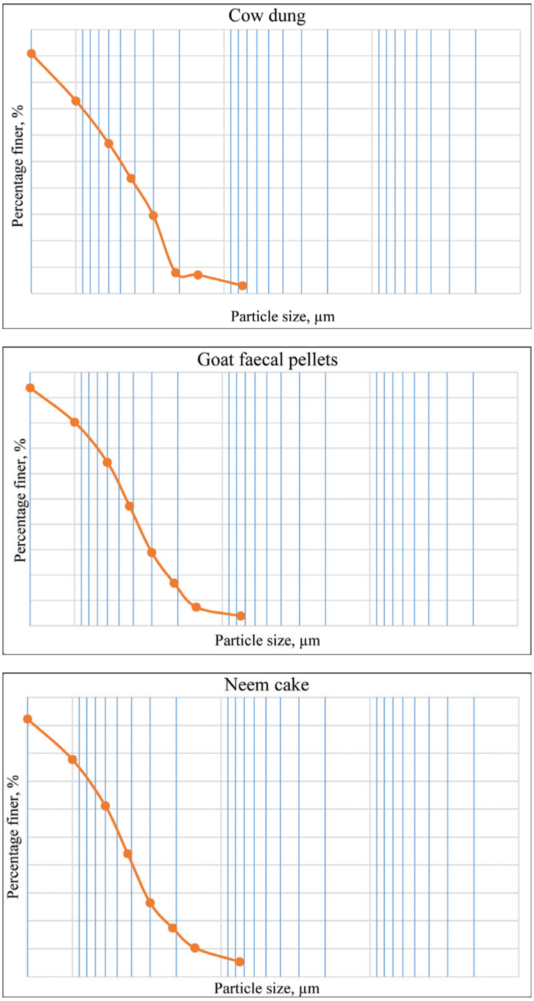

Figure 3. Particle size distribution in cow dung, goat faecal pellets and neem cake

Degree of pulverization

Degree of pulverization or fineness of manure was determined by sieve analysis as explained and obtained data was represented in semi-log graphs as shown in Fig. 3. Particle size distribution curves of manure indicated the fineness of manure at respective sieve sizes.

Fineness of the manure increased with increasing rpm of the blade and has a little effect on discharge. Increase in the rotational speed of the blade affected the fineness of manure irrespective of its discharge. Degree of pulverization increased with increasing the velocity ratio between the driver and driven pulleys.

Since pulverization chamber uses a 5mm sieve, the particle size varied between 4mm and 75µm. Particle size distribution of manure was fine with increase in engine/rotating blade speed. Fine powdered manure helps in easy decomposition into soil but gets affected with drift. To overcome the drift, an air sealed blower casing that can withstand heavy pressure inside and outside the chamber was recommended. Pulverized cow dung was finer because of its less dense nature and easily gets effected by atmospheric wind.

Degree of pulverization also effects the application rate of manure in the field due to atmospheric wind. Increase in the rotational speed of blade increases the degree of pulverization with fine pulverized manure. When the air velocity is greater than the terminal velocity of manure, it lifts the particles. Hence the air velocity could be adjusted to a point just below the terminal velocity (Yang et al., 2007). Pulverized manure is a mixture of fine dust particles which have a very less terminal velocity and settling time. Although a 5 mm sieve was used in the pulverizer, due to the rotational speed of blade it could make a very fine mixture. It is difficult to find the terminal velocity of powdered manure because of its fineness, lack of facilities and its unhygienic nature. A laboratory model of blower was developed and tested.

Table 6. Effect of driftloses on manure pulverization

Type of manure	Input weight (gm)	Output weight (gm)
Cow dung	500	485.2
Goat faecal pellets	500	472.4
Neem cake	500	477.7

Optimization of machine design from manure physical properties

FYM pulverizer cum basal applicator mainly consists of a pulverizer, feeding chute, inlet, blower, frame & hitch, gearbox and flexible discharge

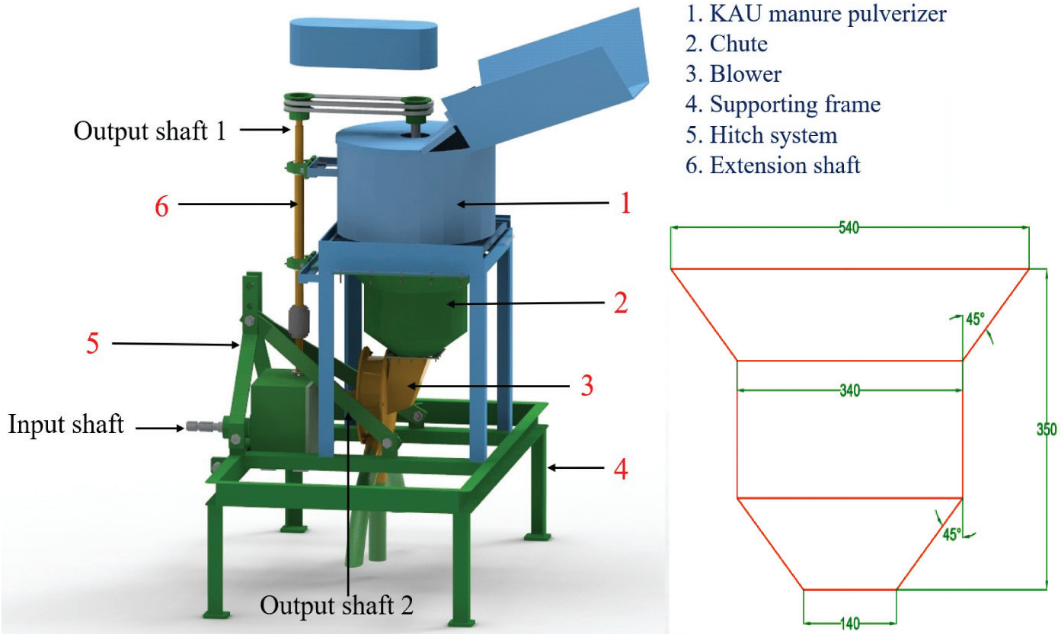

Figure 4. Designed manure FYM pulverizer cum basal applicator

outlets as shown in Fig. 4. Physical properties discussed in the above sections mainly influence the design of feeding chute of pulverizer andblower, blower inlet design, and flexible discharge outlets. Considering bulk density, tapped density and volume required to accommodate a kilogram of manure, working volume of the pulverizer drum was kept as 0.064 m^3 (520×300 mm) and blower feeding chute as 0.034 m^3. Weight of manure that can be held in designed pulverizing drum and blower chute are shown in Table 7.

Angle of repose of the powdered manure was found to be in the range of 38-42°. Hence conveying chute for blowerwas angled at 45° for smooth flow of powdered manure into the blower as shown in Fig. 4.Flexible discharge outlets for delivering manure in the field are also angled above 45° to avoid deposition inside the pipes. Due to finer degree of pulverization, drift will be high. Hence an air tight leakage free setup was recommended.

Table 7. Optimized designed parameters using manure properties

S. No.	Type of manure	Weight of manure that can be held, kg	
		Pulverizer Drum (0.064 m^3)	Blower Feeding Chute (0.034 m^3)
1	Cow dung,	12.6	6.7
2	Goat faecal pellets	31.7	16.7
3	Neem cake	33.4	17.7

Conclusion

In this study, the effect of manure properties on the development of a manure pulverizer cum applicator unit were studied. Physical properties of the manure effected the manure discharge rate through the blower. Bulk density of manure was found to be 195, 492 and 520 kg m^{-3} for cow dung, goat faecal pellet and neem cake respectively. Denser manure gets deposited at the corners and on the other hand less dense manure creates drift due to atmospheric wind. Increase in the moisture content of stored manure due to climatic changes results in unsatisfactory pulverization and application. Hence sun-dried manure was preferred for clump free pulverization which helps in easy suction and application. Tapped density of manure was found to be 308, 668 and 748 kg m^{-3} for cow dung, goat faecal pellet and neem cake respectively. Angle of repose was found to be 43±0.1 deg for cow dung, 37±0.1 deg for goat faecal pellets and 38±0.1 deg for neem cake. Optimum angle of repose of the pulverized manure helped in easy flow ability, suction and conveying of manure. Increase in the pulverizer speed increased the degree of pulverization which helps in easy decomposition of manure in the soil but at the same time it results in drift due to very fine nature.

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