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Original Research

Livestock Waste Utilization Through Manure Pulverizer Cum Applicator

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Abstract

Managing waste produced by animals is one of the most common operation carried out by farmers. A well-managed manure is a valuable resource in providing nutrients for crop production. Farmers usually follow manual manure application practices which involves lot of drudgery and physical stress to pulverize as well as to apply in the field. So, there is a need to create a medium between the farmers and manure application practices by introducing manure pulverizers and applicators. A manure pulverizer cum applicator helps in managing the waste by simultaneous pulverization and application in the field as basal application. The developed unit consists of a KAU manure pulverizer, feed chute, blower, frame & hitch, 3-way right angle bevel-gearbox and an extension shaft. The actual field capacity and efficiency of manure pulverizer cum applicator was found out to be 0.311 ha h-1 and 86.5 % at a forward speed of 2.0 km h^{-1}, 0.356 ha h^{-1} and 79.2 % at a forward speed of 2.5 km h^{-1} and 0.395 ha h^{-1} and 73.1 % at a forward speed of 3.0 km h^{-1}. Maximum field capacity was noted at a traveling speed of 3.0 km h^{-1}. A larger application rate of 1387.1 kg ha^{-1} for cow dung, 1624.4 kg ha^{-1} for goat droppings and 1618.6 kg ha^{-1} for neem cake was noted at an engine rpm of 2500, forward speed of 2 km h^{-1} and a field capacity of 0.31 ha h^{-1}. With increasing the forward speed to 2.5 and 3.0 km h^{-1}, field capacity increases but the application rate is decreased.

Keywords: Application Rate, Applicator, Field Capacity, Manure, Pulverizer, Vermicompost

Introduction

Manures (FYM, vermicompost, oil cakes etc.,) are important resources which provide nutrients that could reduce bagged fertilizer costs and improve the crop growth and performance. As agriculture is facing the problems of soil degradation, loss of fertility and soil health, the use of livestock waste, manure and organic materials is the only way out. A larger portion of nitrogen is made available when the manure decomposes. A well-managed manure is a valuable resource in providing nutrients for crop production. Use of farm yard manure 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). Also, the application of recommended doses of manure at the proper time would stabilize the soil fertility status and hence improves soil productivity.

Utilization of livestock waste for agriculture is an important activity carried out by farmers. Livestock waste viz., cow dung, goat droppings etc., are collected, dried and then spread in the field. Manure produced from the livestock provides a lot of humus, increases soil fertility and helps in achieving improved crop productivity. Studies suggest that pulverizing dried manure into fine powder before applying it in the field helps in easy absorption (Julienne *et al.,* 2010). Manure gets decomposed as soon as it put 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 for the attack of microorganisms (James and Roger, 2000).

Studies revealed that the fine powder is easily absorbed by the soil, easy to handle due to decreased volume and more nutrient concentration (Jotautiene and Bivainis, 2017). Problems like drift and drudgery caused due to manual manure spreading results in health problems. Improper and inaccurate broadcasting causes abnormal and non-homogeneous soil fertility which is against to the purpose of sustainable agriculture. Hence, there is always a need for using innovative manure applicator machines in the farm (Choudhary *et al.,* 2016). Hence, this research work has been carried out to utilize the livestock waste by a tractor powered manure pulverizer cum applicator.

Materials and Methods

The application rate of various manure was observed for different crops according to the agronomic conditions of Kerala state. The components of the machine were developed to suit the various dosages of manure without much variation in the distribution efficiency.

Table 1: Nutritional composition of manure (Pabitra, 2011)

Type of manure	N_2	P_2O_5	K_2O
Cow dung	1.09	0.82	0.7
Neem cake	5	1.1	1.5
Goat droppings	3	1	2

i. *Tractor Powered Manure Pulverizer Cum Applicator*

In the agriculture field level, a tractor is the most commonly available power source. Hence a manure pulverizer cum applicator unit was made as a tractor attachment with PTO as prime mower. The developed parts *viz*., KAU manure pulverizer, feed chute, blower, frame & hitch, gearbox and extension shaft were assembled to form a tractor powered manure pulverizer cum applicator. The supporting frame was made large enough to accommodate all the supporting parts. KAU manure pulverizer was fixed on the supporting frame with nut and bolt making it a removable part. Pulverizer powdered the dried manure which was then collected in the chute below the pulverizer unit. Deposited manure gets sucked through the inlet into the blower unit and discharged through the outlets. Provisions were made to adjust the valve opening, pulverizer blade rpm and blower rpm. Flexible pipes provided at the outlets help in achieving different swath widths in the field. Failure in the model and factor of safety were analysed using theoretical considerations following ASTM standards (Jegan and Jerry, 2017).

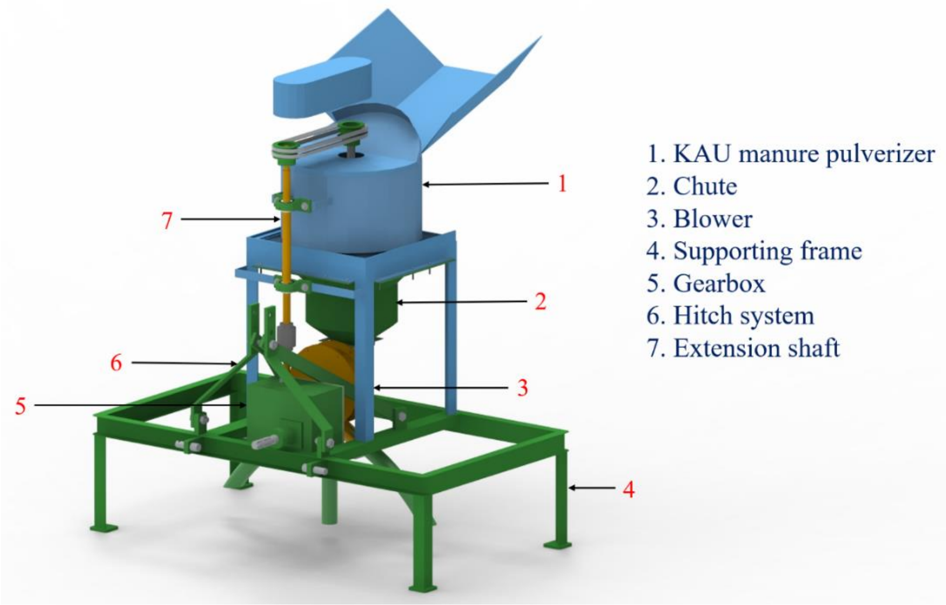

Figure 1: Manure pulverizer cum applicator

ii. *Physical Properties of Manure*

Physical properties of manure directly affect the pulverization capacity, design of blower and manure dissipation (Sahay and Singh, 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 (Reddy and Reddy, 2017). 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 effected the manure discharge rate through the blower. Bulk density of manure was found to be 0.195±0.01 g cm^{-3} for cow dung, 0.492±0.01 g cm^{-3} for goat droppings and 0.520±0.01 g cm^{-3} for neem cake. 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 manure due to improper storage and climatic changes result 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 0.308±0.01 g cm^{-3} for cow dung, 0.668±0.01 gcm^{-3} for goat droppings, and 0.748±0.01 g cm^{-3} for neem cake. Angle of repose was found to be 43±0.1 for cow dung, 37±0.1 for goat droppings and 38±0.1 for neem cake. Optimum angle of repose of the pulverized manure helped in easy flow ability, suction and conveying of manure (Choudhary *et al*., 2016). Increase in the pulverizer rpm 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.

1. Performance Parameters Affecting Pulverizer cum Applicator

i. *Field Capacity*

It is the actual area covered by the machine based on its total time consumed and actual working width under field condition. It is expressed in terms of area covered per unit time of operation. It is calculated by

$$\text{Field capacity (ha h}^{-1}) = \frac{\text{Actual area covered}}{\text{total time consumed}}$$

ii. *Field Efficiency*

Field efficiency is the actual average rate of coverage by the machine, based upon the total operation set time. It is a function of the rated width of the machine, speed of operation and the amount of time lost during the operations. Effective field capacity is usually expressed as hectare per hour (Kepner *et al.*, 1987).

$$\text{Field efficiency} = \frac{\text{Actual field capacity}}{\text{theoritical field capacity}}$$

iii. *Discharge Rate*

Discharge rate is the amount of manure discharged from the blower outlets. It is calculated as kg h^{-1} or kg ha^{-1}. Discharge from the blower outlets depends on the pulverizer output, feed regulator opening and blower rpm. Discharge rate is measured by varying the openings of feed regulator at two stages i.e., at half and full openings. Laboratory procedure can be adopted to measure the discharge from each outlet or as a whole to calculate the application rate (Chowda *et al.*, 2013).

Each outlet is provided with a polythene bag or a bucket to collect the manure and weighed at the end of the test. Sum of the discharges from 3 outlets gives the discharge rate of developed manure applicator. Also output from all 3 outlets should be individually weighed to check for more or less uniformity in discharges.

iv. *Particle Size Distribution*

The finer the particles size the more easy it becomes to decompose in soil. Pulverization performance is evaluated by calculating mean width diameter (MWD) of the manure samples (Landry *et al.*, 2004). By varying the input engine rpm and interchanging the pulleys the blade rotation increases which increases its pulverization capacity. Degree of pulverization or fineness of manure was determined by sieve analysis. Particle size distribution curves of manure indicate 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 (Yang and Evans, 2007). It is calculated by performing sieve analysis with standard sieves in the mechanical sieve shaker. The sieves used for fine sieve analysis are 2mm, 1mm, 600, 425, 300, 212, 150 and 75 IS sieves. Weight of sample retained on each sieve is noted.

Particle size distribution of manure is measured by

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

Where,
Wi = weight of the soil gathered in each grade
W = total weight of the soil sieved
Di = mean diameter referred to each grade
n = number of grades

v. *Swath Width*

Swath width is equal to the number of outlets multiplied by the outlets spacing. The spacing between the outlets was kept constant as 60 cm following the package of practices, KAU. Flexible hoses are preferred in order to make outlets flexible and to prevent bending or breakage when operated in uneven terrains. Flexible hoses are suitable for reaching various row spacings without encountering any sharp corner. The outlets are provided as close as possible to the ground surface in order to reduce the drift.

Table 2: Spacing of various vegetables (KAU POP, 2016)

S. No.	Crop	Spacing (row to row × plant to plant) cm^2
1	Tomato	60×60
2	Okra	60×60
3	Brinjal	60×60
4	Chilli	45×45
5	Cauliflower	60×45
6	Carrot	45×10
7	Beetroot	45×15-20
8	Radish	45×10

2. Selection of Machine Parameters

The parameters of prototype manure pulverizer cum applicator such as speed of tractor, speed ratio between engine rpm and blower rpm and size of valve opening influenced the application rate of manure pulverizer cum applicator. The parameters are optimized to achieve the selected level of application rate.

i. *Speed of Tractor (S)*

Speed of the tractor influences the application rate of manure in the field. Varying the speed of tractor with respect to blower rpm results in varied application rate. Hence the speed of the tractor can be optimised to achieve the required application rate of manure.

ii. *Speed Ratio Between Engine Rpm and Blower Rpm (E)*

Gearbox helps in increasing the speed ratio between the engine P.T.O. and blower. At various levels of blower rpm, varied application rate is obtained along with changing type of manure.

iii. *Size of Valve Opening (V)*

By changing the size of the valve opening above the blower, the application can be varied. Machine is operated at two conditions of valve openings (full and half open) such that feed into the blower changes resulting in a varied application rate of manure.

iv. *Levels of Variables*

Table 3: Description of levels of variables

S. No.	Description of variables	Selected levels	No. of levels
1	Speed of tractor, km h^{-1} (S)	1.5(S_1)	3
		2(S_2)	
		2.5(S_3)	
2	Engine rpm of tractor (E)	1500(E_1)	3
		2000(E_2)	
		2500(E_3)	
3	Size of valve opening, (V)	Full(V_1)	2
		Half(V_2)	
4	Type of manure (T)	Cow dung(T_1)	3
		Goat droppings(T_2)	
		Neem cake(T_3)	

Replications = 3; Total no. of treatments = 3×3×2×3×3 = 162

3. Laboratory Testing

Laboratory testing was done prior to field evaluation in order to calibrate as well as to note the discharge rate of the machine. Calibration of discharge valves was necessary to achieve uniform spread of manure throughout the field.

4. Field Testing

Field testing of prototype manure pulverizer cum applicator was conducted in farm, KCAET Tavanur. The prototype manure pulverizer cum applicator as an attachment to tractor was attached to 65 hp tractor through three-point linkage and P.T.O is attached to gearbox with a universal joint. Prototype was evaluated at a forward speeds of 2.0 km h^{-1} at gear L_1 (high), 2.5 km h^{-1} at gear L_2 (low) and 3.0 km h^{-1} at gear L_2 (high).

Figure 2: Field evaluation of the developed unit

Results and Discussion

Particle size distribution curves of manures indicate the fineness of manure at respective sieve sizes. Increase in the rotational speed of the blade effected 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 rpm. 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.

i. *Field Capacity*

Prototype was evaluated at a forward speeds of 2.0 km h^{-1} at gear L_1 (high), 2.5 km h^{-1} at gear L_2 (low) and 3.0 km h^{-1} at gear L_2 (high). Increasing the travelling speed resulted in a decreased field capacity. The actual field capacity and efficiency of manure pulverizer cum applicator was found out to be 0.311 ha h^{-1} and 86.5 per cent at a forward speed of 2.0 km h^{-1}, 0.356 ha h^{-1} and 79.2 per cent at a forward speed of 2.5 km h^{-1} and 0.395 ha h^{-1} and 73.1 per cent at a forward speed of 3.0 km h^{-1}. Maximum field capacity was noted at a traveling speed of 3.0 km h^{-1}.

ii. *Application Rate*

Forward speed of the travel is inversely proportion to the application rate of the manure. Travelling at a lower speed results in a larger application rate which is good but resulted in a lesser field capacity. A larger application rate of 1387.1 kg ha^{-1} for cow dung, 1624.4 kg ha^{-1} for goat droppings and 1618.6 kg ha^{-1} for neem cake was found at an engine rpm of 2500, forward speed of 2 km h^{-1} with a field capacity of 0.31 ha h^{-1}. With increasing the forward speed to 2.5 and 3.0 km h^{-1}, field capacity as well as application rate decreased.

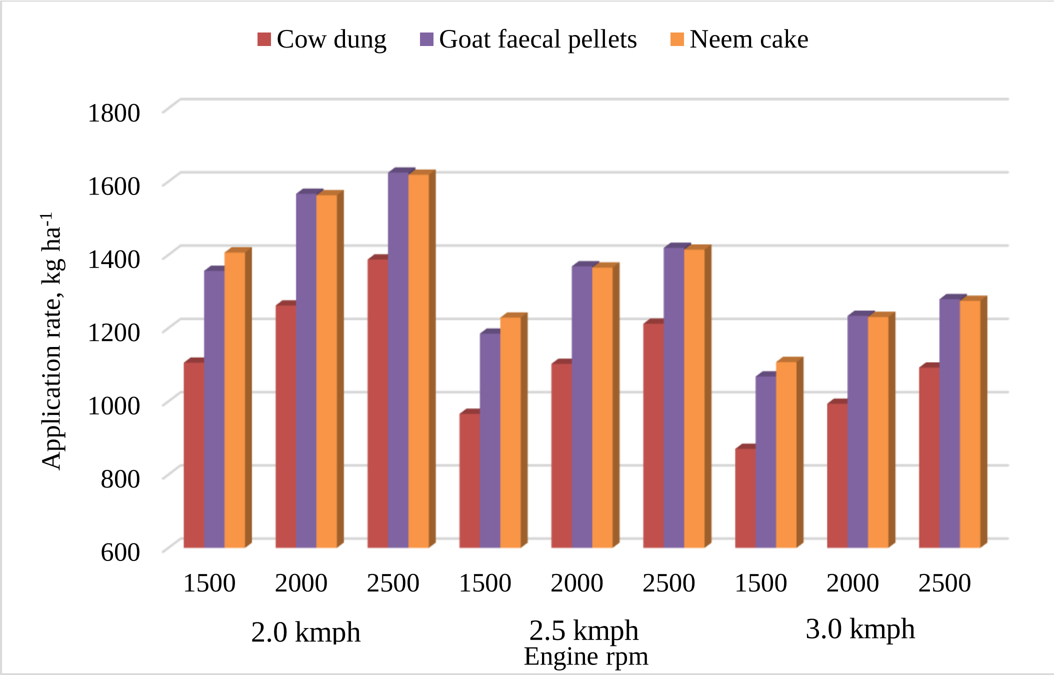

Figure 3: Effect of engine rpm and travelling speed on application rate of manure (Valve at full open condition)

In case of valve at half open position, larger application rate of 1105.5 kg ha^{-1} for cow dung, 1302.3 kg ha^{-1} for goat droppings and 1356.3 kg ha^{-1} for neem cake was found at an engine rpm of 2500, forward speed of 2 km h^{-1} with a field capacity of 0.31 ha h^{-1}.

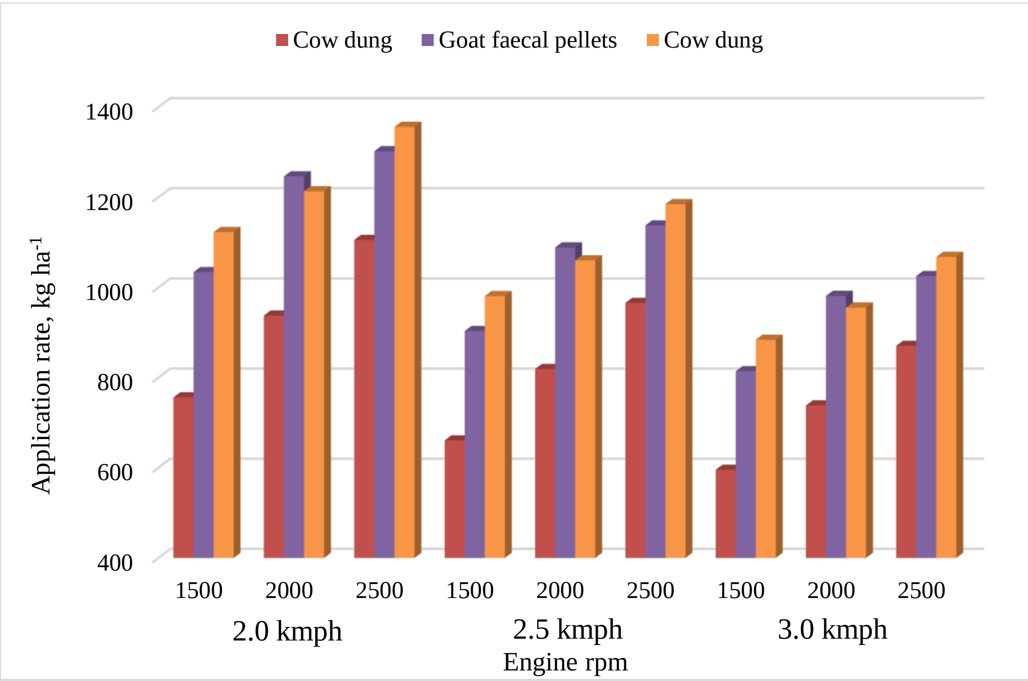

Figure 4: Effect of engine rpm and travelling speed on application rate of manure (Valve at half open condition)

Based on the field studies, the time required for manure application per ha ranged between 3 to 3.5 h at a travelling speed of 2 kmph.

iii. *Optimization of Operational Parameters*

For Okra where the crop is raised in ridges and furrows at a row to row spacing of 60cm, the FYM recommendations as per POP, KAU (2016) is 20t, which is applied as a basal dose. In the case of neem cake it is approximately 4 t ha^{-1}. The discharge chutes of the developed unit i.e., manure pulverizer cum applicator was provided with flexible pipes which help in achieving various row to row spacings for different crops. Valve control mechanism helped in varying the discharge such that larger application rates can be achieved for less dense manures.

From the Fig. 3 & 4, it is clear that the application rate of cow dung was less compared to goat droppings and neem cake because of its less dense nature. So, dosage recommended for cow dung is more compared to other manures. It can be achieved by keeping the valve in full open condition and operating the machine at less travelling speed. From the table 4.5, it is clear that more than 1600 kg ha^{-1} of goat faecal matter and neem cake can be achieved when the travelling speed was limited to 2.0 kmph. Similarly, when the traveling speed is reduced from 3.0 to 2.0 kmph, a larger application rate was achieved. Feeding rate also affects the application rate of manure. Since cow dung is less dense, it can be easily pulverized inside the drum within short period. Also chute below the pulverizing drum was made large and fully open condition which helps in accommodating more powdered manure during field operation to get the required dosage. Readings in Table 4 shows the application rates of selected manures per pass in hectare of land. To achieve larger application rates, number of passes should be increased.

Table 4: Application rates of selected types of manures (for One Pass)

Sl. No.	Travelling speed, kmph	Engine rpm	Application rate achieved in one pass of application (Full valve)		
			Cow dung	Goat droppings	Neem cake
1	2	2500	1387.1	1624.4	1618.6
2	2.5	2500	1211.8	1419.1	1414
3	3	2500	1092.2	1279	1274.4

In the case of Okra, multiple passes of application (for cow dung and goat faecal matter approximately 15 passes and neem cake 3 passes) will be required for application in one hectare.

iv. *Effect* of *Blade Rotational Speed on Degree of Pulverization*

In order to check the effect of rotational speed of pulverizer blade on the discharge rate, four double V-belt pulleys of various sizes were selected. Increase in the rotational speed of the blade effected the fineness of manure irrespective of its discharge (Jayan *et al*., 2017). Degree of pulverization increased with increasing the velocity ratio between the driver and driven pulleys.

Conclusion

Producing healthy crops require supply of organic manures prepared from livestock waste and farmyard wastes. Handling of huge quantity of livestock wastes consumes lot of time, drudgery and labour. To overcome drudgery as well as to carry out pulverization and application simultaneously as a single operation in the field, a tractor powered manure pulverizer cum applicator was developed and evaluated. The actual field capacity and efficiency of manure pulverizer cum applicator was found out to be 0.311 ha h^{-1} and 86.5 % at a forward speed of 2.0 km h^{-1}, 0.356 ha h^{-1} and 79.2 % at a forward speed of 2.5 km h^{-1} and 0.395 ha h^{-1} and 73.1 % at a forward speed of 3.0 km h^{-1}. Maximum field capacity was noted at a traveling speed of 3.0 km h^{-1}. A larger application rate of 1387.1 kg ha^{-1} for cow dung, 1624.4 kg ha^{-1} for goat droppings and 1618.6 kg ha^{-1} for neem cake was noted at an engine rpm of 2500, forward speed of 2 km h^{-1} and a field capacity of 0.31 ha h^{-1}. With increasing the forward speed to 2.5 and 3.0 km h^{-1}, field capacity increases but the application rate is decreased. The performance of the machine during field evaluation was very good with impressive field capacity and application rate.

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Conflict of Interests

There is no conflict of interest.

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