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Manure Pulverizers and Applicators: A Review

S. Sai Mohan[1], P.R. Jayan[1]

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ABSTRACT

Background: Manures (FYM, vermicompost, edible oil cakes *etc*.) are important resources which provide nutrients that could reduce bagged fertilizer costs and improves the crop growth and performance. A well-managed manure is a valuable resource in providing nutrients for crop production. As manure dries, nutrients not only get concentrated on a weight basis, but also on a volume basis due to structural changes. Compared to fresh manure, it is easier to handle and transport because of decreased volume and weight. Hence, it is necessary to pulverize the manure when it is applied to the land.

Methods: Various research works previously carried out on manure pulverizers and applicators have been considered in the study to come up with an idea of developing a tractor powered manure pulverizer cum applicator. Studies concluded the importance of manure pulverization, effect of wind, angle of repose and coefficient of friction in the designing and development of manure dispensing equipment.

Result: Manure pulverizer integrated with tractor PTO along with an applicator was designed and developed. The machine consists of KAU manure pulverizer, feed chute, blower, frame and hitch, gearbox and extension shaft. Power to the gearbox was drawn from the tractor PTO. Dried manure was continuously fed through the feeding chute and rotating blade helps in pulverizing the manure until it achieves a size smaller than the sieve. The pulverized manure reaches the blower unit by means of a chute and gets discharged through the flexible pipes. 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 faecal pellets and 1618.6 kg ha^{-1} for neem cake was noted at an engine rpm of 2500, forward speed of 2 km h^{-1} with a field capacity of 0.31 ha h^{-1}.

Key words: Application, Application rate, Field capacity, Manure, Pulverization.

INTRODUCTION

Agricultural production needs to be stepped up to meet the increasing demand of the expanding population of India. Since expansion of cultivable area has a little scope, yield improvement is a way out which could be achieved through the use of high yield varieties and fertilizers. Soil fertility and crop production can be maintained only by efficient and judicious management of nutrients addition to the soil from external sources (Pabitra, 2011). However, it has been realized that the continued application of chemical fertilizers deteriorates soil qualities and on the other hand, application of organic manures help in building up fertility levels and improves soil quality.

Organic manures such as farm yard manure, green manure *etc*., when incorporated into the soil not only add nutrients but enriches the soil by the fixation of atmospheric nitrogen. The experiments with FYM have shown that the physical properties of soil are improved when compared to the soil treated with chemical fertilizers. Manures (FYM, vermicompost, edible oil cakes *etc*.) are important resources which provide nutrients that can reduce fertilizer costs and improves the crop growth and performance. A larger portion of nitrogen is made available, as and when the FYM decomposes. Application of FYM improves soil fertility, therefore there is 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 improves soil productivity.

[1]Department of Farm Machinery and Power Engineering, Kelappaji College of Agricultural Engineering and Technology, Kerala Agricultural University, Tavanur-679 573, Kerala, India.

Corresponding Author: S. Sai Mohan, Department of Farm Machinery and Power Engineering, Kelappaji College of Agricultural Engineering and Technology, Kerala Agricultural University, Tavanur-679 573, Kerala, India.
Email: samalasaimohan@gmail.com

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As manure dries, nutrients not only get concentrated on a weight basis, but also on a volume basis due to structural changes. Compared to fresh manure, dried manure is easier to handle and transport because of decreased volume and weight. Additionally dehydrated manure has a consistent texture and is easier to apply to gardens. Dehydrated manure has a lower pathogen and weed seed content than fresh manure. When manure is dried up to 10-17% of moisture content and ground into a fine soil like texture, nutrients are more concentrated and the soluble salt level is probably higher in dehydrated manure than in locally available farm manure.

Due to the availability of large farming area, heavy equipment's like solid and liquid manure applicators are

commonly used in many developed countries. The application of manure has become mechanized in other countries 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 drops a small amount of manure in the form of a heap. These heaps are later spread around manually with spades, which is 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.

Manure gets decomposed as soon as it put on the soil by the action of microorganisms present in the soil. 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 better the surface area exposed for the attack of microorganisms. Also scientific 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.

Hence, it is necessary to pulverize the manure when it is applied to the land. Considering the Indian farm holding capacities a small scale tractor powered machinery that can both pulverize the manure and apply in the field is recommended. In view of these, a research work was undertaken to study the various available manure pulverizers and applicators and develop a tractor operated machine that can perform simultaneous pulverization and application in the field as a basal application.

MATERIALS AND METHODS

Research works carried out on manure requirements of different soils, physical properties of manure, bullock drawn pulverizers and applicators, machine and performance parameters affecting pulverizer cum applicator are discussed here. Study was carried out as an M.Tech research work to develop a tractor powered manure pulverizer cum applicator in Kelappaji College of Agricultural Engineering and Technology, KAU, Tavanur.

Properties of manure

Reiman *et al.* (2009) studied the impacts of placing the manure at depths on crop yields and N retained in soil. Water infiltration, changes in soil N and P for up to 30 months, crop yield monitoring for three seasons were carried out at deep manure injection (45 cm), shallow manure injection (15 cm) and conventional fertilizer application per site. The fertilizer application rates for the conventional method were 168 kg N ha^{-1}, 20 kg P ha^{-1} and 46 kg K ha^{-1} respectively and were applied prior to tillage and planting each year. Results indicated that the deep injection had 31, 59 and 44 kg N ha^{-1} more than the shallow injection treatments at 12, 18 and 30 months after application. Deep injection system increased the corn yield because of the increased nitrogen use efficiency however there was no impact in soybean yield.

Julienne *et al.* (2010) studied the effect of manure type, application rate and application method on odours from manure spreading. Basal application of manure was an effective means of recycling the nutrients to increase the soil nutrient content. Also odours from manure application activities causes potential nuisance to neighbours and creates difficulties for the expansion of the livestock industry. The study aimed at assessing the efficiency of subsurface application with reducing odours from both solid and liquid manure applications. The results indicated that odour concentrations from subsurface application plots were lower than the concentrations of surface application plots. Due to better manure coverage in subsurface application it was seemed to have a larger impact on reducing odours from solid manure than liquid manure.

Elizabeth *et al.* (2012) conducted studies on the effect of manure on soil organisms and soil quality. The short and long-term effects of manure amendments, processes affecting yield at initial and final application were studied. The addition of manure to soil results in increased yields of nutrient deficient cropping systems, by addition of nutrients. Long-term increase in yield may be due to delayed nutrient release or increase in soil quality. Manure application showed profound effects on soil structure, chemistry and organisms and have also been found to suppress soil pathogens and diseases.

Jotautiene *et al.* (2017) carried out investigations on geometrical and aerodynamic parameters of granular manure fertilizers. Granular organic manures of two different sizes were used in the study. Various parameters like aerodynamic resistance coefficient, particle velocity and coefficient of flow rate were determined. To predict the trajectory of individual granular manure particles from the disc, a theoretical model was developed. The study concluded that coefficient of flow rate was dependent on the pellet diameter. Also by increasing diameter of the pellet the coefficient of flow rate was decreased, whereas decreasing the pellet diameter increased the flow rate.

Working pulverization models

Jayan *et al.* (2017) developed and tested KAU manure pulverizer. It consisted of a pulverizing drum, blades, sieve, feeding hopper and supporting frame. The objective of the study was to powder the dried manures like cow dung, goat faecal pellets and neem cake. Dried manures were fed into the pulverizing drum from the hopper through the feeding chute and get pulverized due to the rotation of pulverizing blade. An electric motor (AC) was used as a prime mover for working. The developed manure pulverizer was tested to optimize the manure and machine parameters. The capacity of the pulverizer was found to be 500 kg h^{-1}.

Jitendra *et al.* (2018) evaluated the performance of grinding machine developed for commercial manufacturing of quality vermicompost. The machine consisted of a motor, gear box, adjustable blade, bearing, drum and an adjustment blade shaft. The electric motor operated the batch type media mixer having blade type agitators provided on a shaft

rotating at 210 rpm for thorough mixing. The mixer had a capacity range varying from 250 to 300 kg per batch and takes 6 minutes for thorough mixing of vermicompost. The grinding machine was found to be best for 30 kg dry leaf wastes on operation for six minutes. The pH value of manufactured vermicompost was found out as 5.1 for black tea and 7.1 for poultry manure.

Studies on manure applicators

Glancey (1996) developed an applicator for side dressing row crops with solid waste. The objective of the applicator was to use the poultry waste as manure for meeting nutrient demand in crops. A laboratory test was conducted using a single screw conveyor for metering the solid manure and delivering it in between the rows. The side dresser was attached to New Holland beater type manure spreader. A manure application rate of developed applicator was obtained as 1810 to 11000 kg ha^{-1} with a nitrogen application rate of 27 to 170 kg N ha^{-1} respectively.

Mari (2000) carried out the performance evaluation of a tractor operated manure spreader. The objective of the study was to assess the performance of the spreader so that farmers can be advised to adopt the machine for better results. Spreader was powered by FORD-6610 diesel operated engine and maintained at low gear. Moisture content of manure was maintained at 19.2% throughout the experiment. The results showed that a travel reduction of 3.2% was recorded due to time lost in turning, fuel fillings and adjustments. A field capacity of 1.26 ha h^{-1} was obtained with a fuel consumption of 20.13 l h^{-1}. Cost economics revealed that manure spreading with spreader costs Rs.322 for one hectare whereas manual spreading costed Rs.640.

Suthakar *et al.* (2008) developed and evaluated the field performance of a tractor PTO operated manure spreading attachment to a two wheel trailer. The machine consisted of a manure tub to load the manure, an endless chain conveyor for conveying the manure towards the rear end of the trailer and a hydraulically operated spreader drum to shear off manure. The desired application rate of the manure was observed for the forward speed of 2.31 km h^{-1} and the chain conveyor speed of 1.51 m min^{-1} with the effective width of 1.20 m and a time saving of 50-60% when compared to the conventional method. It can also be used as a trailer by just shifting a door whenever the trailer is required for transportation. Minimum (8.13 tonnes ha^{-1}) and maximum (18.40 tonnes ha^{-1}) application rates were observed for the forward speed of 4.00 km h^{-1} and 1.88 km h^{-1}, respectively.

Sapkale *et al.* (2010) conducted the performance evaluation of tractor operated manure spreader. The spreader used 45 HP tractors through the hitch point with a 540±rpm PTO speed to operate the rotary blades of manure spreader. The distribution pattern was found uniform over the area but a little variation was encountered due to clods in manure. An average field efficiency obtained was 71.55%. Actual field capacity at a forward speed of 2.438 km h^{-1} ranged between 1.39 to 1.47 ha h^{-1}. A discharge rate of 5.43 to 5.89 t ha^{-1} at 2.438 km h^{-1} was noted. The cost of spreading was reduced to 72% and time saving of 94% compared to manual broadcasting.

Singh and Singh (2014) designed and developed an animal drawn farm yard manure spreader. The idea of transforming the existing bullock carts into FYM spreaders was taken as a base for the study. Accordingly an animal drawn FYM spreader was developed for uniform spreading of manure in the field. It consisted of a manure box, a spiral box for spreading unit and a hitch beam. The auger crushed the lumps and helps in spreading the manure. Chain and sprocket drive was provided for rotating the auger. The developed animal drawn manure spreader was found to have a capacity of 480 kg per hour. At an operational speed of 2.4 km h^{-1}, the manure application rate was found out as 5 to 10 t ha^{-1} with a manure delivery rate of 0.38 to 0.74 kg s^{-1}.

Jain and Lawrence (2015) conducted the performance evaluation of bullock drawn farm yard manure spreader to spread farmyard manure uniformly at a desired rate in the field. The commonly used organic manure was used for evaluating the performance of spreader. The draft requirement of spreader at no load, partial load and full load condition was found to be 78, 227 and 294 N respectively. The results inferred that application rate was directly proportional to the area of opening of delivery slot and was varied between 6.23-13.35 t ha^{-1}. Accordingly the manure delivery rates were also varied between 0.38-0.83 kg s^{-1}.

Choudhary *et al.* (2016) conducted studies on characteristics of bio slurry and FYM for mechanized application. Spreader performance was mainly dependent on the physical and frictional characteristics of the material. Major characteristics of the manure like bulk density, moisture content, dry matter content, angle of repose and angle of friction were studied for the development of spreader. The dry matter content was observed decreasing due to increasing moisture content and affected the flow characteristics of manure. They also concluded that the angle of repose effected the design of hopper and conveying systems.

Patil and Munde (2017) designed and developed an animal drawn manure spreader cum cart. Since animal power is affordable and accessible to small land holdings, the compatibility of animal cart as a manure spreader was found effective. The spreader consisted of a chassis having two iron wheels, axle assembly, flat and peg tooth agitator, manure box and fastened through yoke and harnesses. A peg tooth type agitator on upper side and flat type agitator on bottom side to a shaft were provided inside the manure box. The capacity of the cart was 500 kg. Also reported that on varying the opening area of the cover from 0.04 m^2 to 0.16 m^2, the application rate varied between 2.46 to 10.06 t ha^{-1}. The draft and power requirement of manure spreader were 637 N and 0.46 Kw respectively. Also effective field efficiency of 84% was observed at an operational speed 2.51 km h^{-1} at a field capacity of 0.21 ha h^{-1}.

Kothari *et al.* (2018) designed and developed a cow dung spreader aimed to reduce the manual efforts.

To prevent the loss of ammonia and other nutrients from manure proper application of manure to land is essential to prevent the pollution of land. The machine consisted of a trolley, conveyor, centrifugal wheel and a rotating plate. Conveyor carried the manure in the forward direction and drive is taken from PTO by a ratchet mechanism rotating at 100 rpm. Crushers were provided along with centrifugal wheel, that gets drive from PTO with a chain drive rotating at 135 rpm. Crushers crushed the oversize manure and supplied to centrifugal wheel. Rotating plate at 450 rpm spreads the manure in the field. Change in application rate was observed with change in forward speed of tractor or PTO speed.

Singh *et al.* (2018) worked on the laboratory and field evaluation of subsoiler cum vermicompost and soil amendments applicator. A study was conducted to determine the effect of subsoiling and deep placement of organic and inorganic fertilizers at different depths up to 400 mm. Experiment was carried out at three moisture contents of vermicompost, press mud and FYM and for soil amendments like Gypsum, lime, cement and rice husk. The machine was also tested at 250, 300, 350 and 400 mm depths of operation for changes in dry bulk density, specific draft and wheel slippage. Bulk density was found to be uniform throughout the soil profile and observed a maximum of 13.88%. The field capacity of machine was varied between 0.16 and 0.30 ha h^{-1} at two operating speeds 2.0 and 2.5 km h^{-1}.

Cost economics of manure spreader

Kumara and Dwivedi (2010) analysed the economics of organic farming over conventional farming in India. Economic study of organic farming was carried out in different crops to assess the production, productivity, energy inputs and net income levels. Results concluded that the production cost of organic farming is lower in both cotton and sugarcane crops. The cost of production per quintal of paddy under organic farming was 8% lower than the conventional farming. Sugarcane yield per acre was found out as 12% higher in organic farming than the conventional. Also the efficiency levels of production system are lower in organic farming when compared to conventional farming.

Rahul *et al.* (2015) carried out field and economic studies of a tractor operated manure spreader with rear vertical rollers. The moisture content and density of manure used for evaluation varied from 30-40% (w.b.) and 430-480 kg m respectively. The loading capacity of machine varied from 1.0-1.2 tonnes. The forward speeds are varied between 2.0 to 7.0 km h^{-1} keeping the engine rpm at 1400, 1500 and 1600 during operation. The field capacity and mean fuel consumption varied from 0.11 to 0.55 ha h^{-1} and 5.35-7.80 l h^{-1}, while the manure application rate during field experiments varied between 10.58-36.37 t ha^{-1}. Using a tractor operated manure spreader the time and cost incurred in spreading manure was saved by 66.17% and 50.43% compared to traditional techniques.

Design of manure pulverizer cum applicator

Kerala Agricultural University, Tavanur developed a manure pulverizer that uses drive from a single phase, 2.0 hp electric motor that helps in pulverizing the manure. Due to the non-availability of electric power in remote areas and fields, use of tractor power is a viable solution. For operating in such situations, use of tractor p.t.o for operating a pulverizer along with applicator is an added advantage. Hence it is envisaged to utilize the tractor p.t.o power for operating KAU manure pulverizer for basal application of manures in soil directly.

The developed machine consists of KAU manure pulverizer, feed chute, blower, frame and hitch, gearbox and extension shaft. Power to the gearbox was drawn from the tractor PTO. The supporting frame is made large enough to accommodate all the supporting parts as shown in Fig 1. Dried manure was continuously fed through the feeding chute and rotating blade helps in pulverizing the manure until it achieves a size smaller than the sieve. The pulverized manure reaches the blower unit by means of a chute and

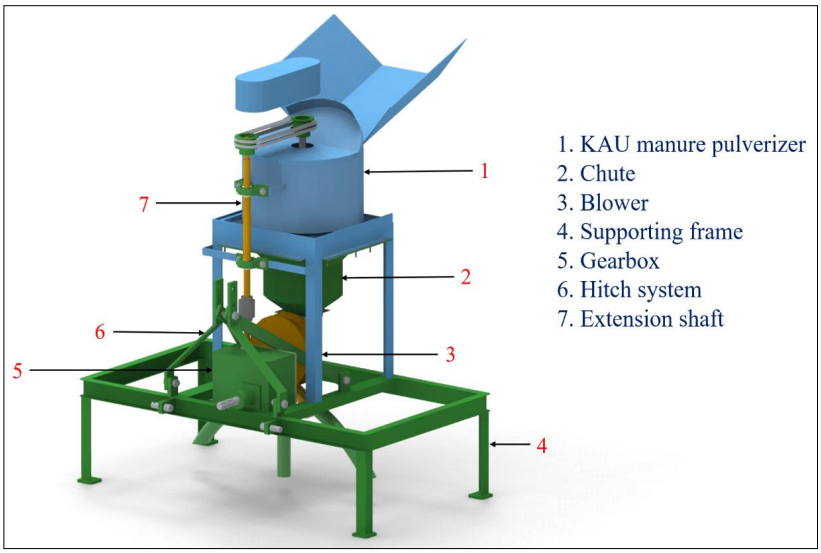


Fig 1: Manure pulverizer cum applicator.



Fig 2: Tractor powered manure pulverizer cum applicator.

gets discharged through the flexible pipes. Flexible pipes helps in reaching different row spacings.

Field testing of prototype manure pulverizer cum applicator was conducted in farm, KCAET Tavanur (Fig 2). The prototype manure pulverizer cum applicator as an attachment to tractor was attached to 65 hp tractor through three-point linkage and is attached to gearbox with an universal shaft.

RESULTS AND DISCUSSION

Physical properties of manure directly affect the pulverization capacity, design of blower and manure dissipation. 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. Particle size distribution curves of manures 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. 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.

For Okra where the crop is raised in ridges and furrows at a row to row spacing of 60 cm, the FYM recommendations as per POP, KAU (2016) was 20 t, which is applied as a basal dose (POP KAU, 2016). In the case of neem cake it is approximately 4 t ha^{-1}. So for such row crops, basal application and running along the rows with the developed unit attached to tractor was easy. 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.Flexible pipes helps in reaching different row spacings.

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 faecal pellets and 1618.6 kg ha^{-1} for neem cake was noted 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 increases but the application rate was decreased.

CONCLUSION

The study was undertaken to put forth the need for introducing small and medium scale manure pulverizers and applicators on the field. Due to scarcity in labour as well as increased wage rates it was difficult to manage manual broadcasting of manure. Manure pulverizers that can grind the clods into fine powder, run by electricity are readily available. Due to the non-availability of electric power in remote areas and fields, use of tractor power is a viable solution. And operating the pulverizer along with an applicator will be an added advantage. Hence it is envisaged to utilize the tractor PTO power for operating both pulverizer and applicator for basal application of manure in soil directly. Considering all the issues, a manure pulverizer cum applicator was developed and evaluated. The results showed a very good capacity and optimum application rate with minor variation in discharge outlets. Flow regulators are provided at each outlet to minimize this variation.

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Conflict of interest

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