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Research paper

Evaluation of some effective parameters in performance of a helical two-sided manure distributor

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ABSTRACT

Organic manures play an important role in improvement of soil fertility, increasing of crop yield and quality. The beneficial advantages of manure depend firstly on the method of spreading. Usually current manure spreaders cannot broadcast manures with different moisture contents and have non-uniform application rate. So the main objective of this research is performance evaluation of a new helical two-sided manure distributor that would be capable to spread manure at different moisture contents with long distribution width in uniform patterns. Experimental evaluation of the machine performance at two moisture content of manure in three forward velocities and three rotational speeds of drum showed that the moisture content of manure and rotational speed of drums had significantly effects ($p = 0.01$) on the distribution width and uniformity of the distribution pattern. The maximum distribution width of the machine at moisture content of 23% w.b. and 54% w.b. and in 1000 rpm rotational speed of drum were 19.3 m and 23.3 m respectively. Results indicated that the manure distribution uniformity increased by increasing the manure moisture and the distribution pattern of machine has an acceptable correlation with oval distribution pattern ($p = 0.05$).

1. Introduction

In recent years, chemical fertilizers consumption is increased exponentially throughout the world that causes serious social and environmental problems. The extensive use of chemical fertilizers might cause contamination of soils due to the presence of toxic metals, which could result in negative impact, such as loss of ecosystems, decrease of agricultural productivity, economic damage and health problems for humans and animals (McLaughlin et al., 1996; Isherwood, 2000; Mehmood et al., 2009). Organic manures play an important role in improvement of soil fertility, increase of crop yield and quality. Several studies have shown the beneficial effect of animal manure on soil structural quality by reducing balk density, runoff and soil erosion (Gilley and Risse, 2000; Wortmann and Walters, 2006), increasing macro and micro-porosity (Celik et al., 2004; Hati et al., 2007), water infiltration rate and hydraulic conductivity (Fares et al., 2008; Uzoma et al., 2011). Manure is an important source of nutrients for crop production (Zingore et al., 2008) and manure application can improve nutrient status and increase soil organic carbon (SOC) levels that is suitable for food security and agricultural sustainability (Dai et al., 2013). All over, the beneficial advantages of manure depend on the method of spreading. The spreading of manure is an important step in cultivation for agricultural production. Unsuitable methods in spreading manure cause to decrease crop production (Duhovnik et al., 2004). The main problem of manure distribution is the moisture content of manure, i.e. the high moisture manure prevents suitable distribution and so common manure distributors cannot distribute manure with high moisture content.

Considering the importance of spreading pattern of manure, some researchers investigated about optimal spreading conditions. Temple et al. (2014) evaluated a spin-type centrifugal spreader using fresh and aged poultry litter. The result showed that for mass broadcast application, the distribution pattern of the fresh litter displayed best fit with 4th order polynomial, while the distribution pattern of the aged litter displayed best fit with 6th order polynomial. Suthakar et al. (2008) studied the performance of a manure spreader attached to a two wheeled trailer. The result showed the application rate has a linear relationship with the forward velocity of tractor and the speed of chain conveyor. The optimum forward velocity of tractor and chain conveyor speed was 2.31 km/h and

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1.51 m/min respectively.

Commonly all studied manure spreaders were equipped to chain conveyor for conveying the manure to distributor units. The chain conveyor systems are suitable for dry and granular material and have high friction and wear (Sadleir, 2003). However screw conveyors are appropriate device for transporting sticky and wet material (such as fresh manure) and in compared to chain conveyor do not require large numbers of operating staff or continual maintenance (Newman and Van, 2006). Current manure spreaders discharge manure and spread from the end of hopper that reduces distribution width (Suthakar et al., 2008; Sapkale et al., 2010; Temple et al., 2014) and cannot broadcast moisturized manures and has non-uniform application rate. Considering above mentioned restrictions, the main objective of this research is evaluation the performance of a new helical two-sided manure distributor machine. The machine would be capable to spread manure in long width and uniform distribution patterns in transverse and longitude directions and would be suitable for manures with different moisture contents.

2. Materials and methods

2.1. Design and construction of manure spreader

Design principle of this manure spreader was based on maximum distribution width and spreading of wet manure. The machine was designed to be linked to drawbar and was powered by PTO shaft of the tractor (Fig. 1a). Some main components of the constructed machine consisted of hopper, conveying unit, distribution unit, drawbar coupling system and power transmission system. Trade-off for definition of hopper volume is based on two scenarios; a) a large and heavy hopper causes soil compaction and b) a small hopper requires more traffic that leads to more energy consumption and possibly to soil compaction as well. So volume of hopper was determined by distribution rate in hectare. Required amount of manure is recommended 20–60 ton/ha according to soil and crop type (Mansouri-Rad, 2009). Therefore the volume of hopper was determined 6 m^3. Conveying unit of the manure spreader included two longitudinal augers (screw conveyor) in the bottom of the hopper. The augers moved manure in a linear path with screw flights by rotating around the shaft. Grips were mounted on the middle of shaft spirally. The grips passed manure to outlet throat and distribution drums (Fig. 1c). Advantages of this type of conveying were lower construction cost, lower maintenance and no limitation for wet manure in comparison with chain conveyor. The manure distribution unit consisted of two drums in both sides of hopper and two meshing plates on apron of the hopper. The drum contained straps and rectangular plates that were placed on the shaft (Fig. 1b). Manure was broadcasted on the field by centrifugal force that was applied by rotational motion of drums.

For distributing manure under the hopper, two adjustable meshing plates were installed under the grips that could be able to move in longitudinal direction of the machine and discharged manure under the machine, because the drums could not be able to spread manure under the machine (Fig. 1d). Adjustable gates were also installed at the both sides of hopper for adjusting the application rate of manure.

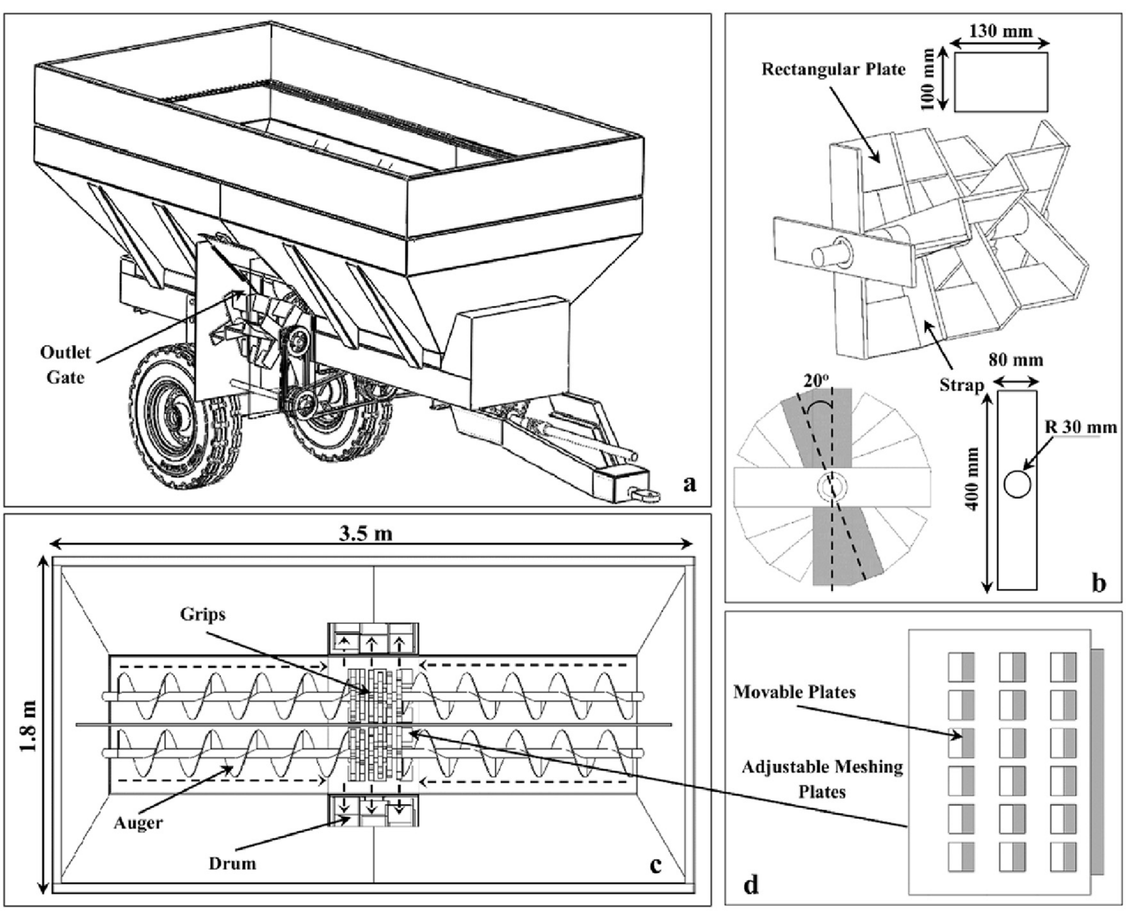

Fig. 1. (a) Helical manure distributor machine, (b) distribution unit of the machine (drum), (c) top view of the machine, (d) adjustable meshing plates.

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