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Effects of Disc Speed and Height of Flow Mechanism of a Solid Manure Spreader on Uniformity of Spreading and Swath Width

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ABSTRACT: The aim of this study was to investigate the effects of disc speed and height of flow mechanism of a solid manure spreader in order to maintain uniformity of spread and swath width for optimum crop growth. The study was done using complete randomized design with three factors considered: tractor forward speed, height of flow mechanism (broadcasters) gate opening rates, (15, 30, 45cm) and disc speed (150, 300, 450rpm) applied according to ASAE S341.2, 1999 test code. Results obtained and compared with an imported spreader shows that the developed spreader recorded the highest application rate of 4082.1kg/ha against that of the imported spreader of 1875.3kg/ha while the swath width was 9.5m compared to 9.0m of the imported. Results obtained also shows that the spreader gave a more uniform spread pattern of manure at a lower openning of 15cm height of flow mechanism and lesser disc speed of 150rpm. Disc speed and height of flow mechanism were found to be the major determining factor influencing spreading uniformity and swath width of cow dung manure for optimum crop growth.

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Keywords: Spreader, Swath Width, Uniformity, Disc Speed, Flow Mechanism

Most peasant farmers today apply manure by band placement and manual broadcasting methods (Singh and Singh., 2014). This methods are labour intensive and relatively time consuming with low productivity. The application rate per unit area also results in non-uniform application. Solid manure was also observed to have lost about 21% of its nitrogen to the atmosphere through these methods (Lague *et al.*, 1994). In attempt to reduce the drudgery and loses involved, varieties of manure spreaders were imported for distribution to farmers at subsidized rates by various tiers of government. However, most farmers could not afford or operate them due to high cost, complexity in design and higher weights that requires higher capacity tractors to operate them (Ojeniyi, 2000).

Although few mechanical manure applicators are available in various designs and configurations, suitable design as well as calibrating the spreader at optimum setting that would ensure even spread of the manure becomes paramount. The objectives of this study, therefore, was to investigate the effects of disc speed and height of flow mechanism of a solid manure spreader in order to maintain uniformity of spread swath width for optimum crop growth.

MATERIALS AND METHODS

Solid cow dung manure obtained from the Institute for Agricultural Research (IAR) Animal Farm, Ahmadu Bello University Zaria was used for this study. A set of kits available for this calibration include a set of 7 wooden boxes (0.5 x 0.5 x 0.2m^3) as suggested by Larry and Allan (2012). A 100kg capacity weighing balance (WT1000KF, 0.001 Accuracy), digital tachometer (RPM, 0.05% Accuracy), stop watch, 100m measuring tape, nylon bags and tags were used. Tins to collect samples were also used in determing moisture content of the soil.

The traditional method for evaluating a field machine uses a series of trays placed on the ground in a line perpendicular to the direction of travel as suggested by Allan *et al.* (2012). One or more passes of the spreader in the same direction deposits material in the trays. A plot of the material weight from each tray at 0.6 m interval, versus the location of the tray gives a visual picture of the distribution pattern. Material from the trays is poured into nylon bags and marked at each calibrations chosen and the height of manure by kilogram in a graph assists in visualizing the spread pattern.

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Collecting trays: Seven collecting trays were put in a line on the ground for collecting broadcasted particles to construct broadcasting pattern of the spreader, performing broadcasting experiments and determining uniformity pattern specify the factors affecting on it. According to ASAE S341.2 (1999), trays were put symmetrical in a row with equal distances to the longitudinal center line of the tractor. The distance between all trays was equal, except for the middle one. The spreading uniformity was determined by placing a row of collection trays (0.5 m x 0.5 m m x 0.2 m), 0.6 m apart from each other at right angles of the direction of travel at 5 m distance as described by Lawrence and Yule, (2005). The weight of manure spread and collected in boxes was plotted against the distances between collection trays to have a visual view of the spreading uniformity. The moisture content of the manure was determined using ASAE Standard S410 (ASAE, 1983). All collected samples were weighed to obtain the bulk weight and then oven dry at a temperature of 103 ± 2°C to constant weight to obtain dry weight. After cooling, the moisture content (MC) of each sample was calculated and average result taken

$$MC = \frac{w - w_d}{w_d} \text{x } 100\% \qquad (1)$$

Where: M_{db} = Moisture content on dry basis (%); w = Initial mass of sample (g); w_d = Mass of dry sample (g)

Experiment Procedure: The moisture content of manure (cow dunk) was measured using dry weight method. Weights of 40 kg were measured and used for each experiment on a 100 m x 25 m field. After uploading the measured manure into the hopper, the stop watch starts simulteneously as the the spreading begins, effective time, delay and total time are recorded. The swath width aslo recorded at intervals and average taken. The independent variable were tractor forward speed, disc pheripheral speed, height of flow mechanism and manure type. The tractor forward speed was taken at 20 km/hr, three levels of PTO speed of 150, 300, and 350 rpm along side with three levels of height of flow mechanism of 15, 30 and 45 cm were considered. Manure type taken, was Cow Dung. The experiment was laid in CRD with three replications. The parameters gave $3 \times 3 \times 3$ factorial experiment fitted in Complete Randomised Design (CRD). The time taken for the machine to complete spreading operation in a constant forward speeds (20 km/hr) using 40 kg of manure at every replicate of F_1, F_2 and F_3 calibrations, was recorded with a stop watch that reads both minutes and seconds. The flowrate was determined in kg/hr, using the total effective time in spreading manure during the laboratory test. Moisture content for manure was determined to be 12.4 % after the manure samples were oven dried and measured consistently until there is no change in weight at 130°C. the results where measured and recorded. The optimum moisture content for spreading solid manure is 15 % as cited in Rick *et al.* (2015).

Performance Evaluation of the Developed Manure Spreader: The developed machine was evaluated based on four parameters viz: field efficiency, uniformity of the spreader, effective width and effective field capacity of the spreader.

Determination of Field Effieciency of the Spreader: The spreading efficiency of spreader and time required to spread the manure were determined using equations (2) and (3). It gave the actual time required to perform the operation. Time loss due to overlap, turning, loading and unloading the materials were duly accounted.

$$FE = \frac{T_t - T_d}{T_t} \qquad (2)$$

$$T_t = (T_e + T_d) \qquad (3)$$

Where: FE = Field efficiency; T_t=Total time required to spread manure including delayed time, min; T_e = Total effective time in spreading manure, min; T_d = Total delay time required for cleaning, turning, reloading and repair, min

Uniformity of the spreader: The ASAE 341.2 standard collection tray method was used to determe the spreading uniformity by placing six collection trays at right angle to the direction of travel of the spreader, Lawrence and Yule (2005). Each of the trays has a dimension 0.5 m x 0.5 m x 0.3 m. The distance between the trays was 0.6 m. the sample from each collection tray was collected in polythene bags and labelled. The samples were weighed and presented graphically.

Determination of effective width of the spreader: The effective width of the manure spreader was measured using a tape after manure have been spread in three radomly places and the average taken.

Determination of effective field capacity of the spreader: The effective field capacity of the spreader was calculated using Equation (4).

$$C_{eff} = \frac{SW}{10} \times FE \text{ , ha/hr} \qquad (4)$$

Where: C_{eff} = Effective Field Capacity of the manure spreader, ha/hr; S = Optimum forward speed of the tractor during the operation, km/hr; W = Effective swath width of the manure spreader, m; FE = Field efficiency

RESULTS AND DISCUSSION

The developed tractor-powered manure spreader was tested and evaluated. Results obtained were also

compared with an imported manual spreader as discussed below:

Spreading Capacity of the Developed Manure Spreader and Imported Spreader: A preliminary test was carried out on the IAR imported manure spreader. The spreader was tested on a stationary position and a selected gear speed that runs at 8 km/hr. The readings recorded were shown in Table 1. The highest average spread capacity was recorded at height of flow mechanism setting 'U' with 2000 kg/hr and swath width of 10 m, the lowest average spread capacity was 432.79 kg/hr with a swath width of 8.63 m at flow rate setting 'A'. Comparing the both manure spreaders from Table 1. It was observed that the constructed spreader spreads more manure in a given time compared to the imported spreader.

Table 1: Spread Capacity, Time and Swath Width of the Spreaders

Flow rate settings	Rep	Time (min)	Machine Capacity (kg/hr)	Swath Width (m)	Average Time (min)	Average Capacity (kg/hr)	Average Swath Width (m)
Imported Spreader							
	1	5.57	430.87	8.6			
A	2	5.43	441.98	8.8	5.54	432.79	8.63
	3	5.64	425.53	8.5			
	1	3.5	685.71	9.6			
K	2	3.85	623.37	9.9	3.66	659.75	9.8
	3	3.63	661.16	9.9			
	1	1.24	1935.48	9.8			
U	2	1.42	1690.4	10	1.21	1875.21	10
	3	1.2	2000	10			
Constructed Speader							
	1	1.27	2862.02	7.37			
F1	2	1.25	3105.92	7.70	0.92	3011.31	7.50
	3	1.06	3065.98	7.43			
	1	1.27	3634.10	8.70			
F2	2	1.26	3587.11	9.10	0.85	3706.37	9.01
	3	1.21	3897.89	9.23			
	1	1.23	4109.93	10.50			
F3	2	1.23	4005.05	10.33	0.82	4082.13	10.37
	3	1.09	4131.41	10.27			

Spreading Uniformity of the Developed Spreader: According to the ASAE 341.2 as cited by Lawrence and Yule (2005), standard collection tray method of spreading (0.5 m x 0.5 m m x 0.2 m), 0.6 m apart from each other at right angles of the direction of travel at 5 m distance was used. The weight of manure spread and collected in boxes was plotted against the distances between collection trays to enable visual view of the spreading uniformity. Figures 1 and 2 shows the effect of height of flow of control mechanism and disc speed respectively on uniformity of manure spread for the Imported manure spreader. It gave a more uniform distribution pattern at calibration 'K' and 'U' compared to 'A', which gave an offside distribution pattern as shown in Figure 1, this agrees with the findings of Larry and Allan (2012). In terms of the disc speed, spreading was more uniform on 150 rpm and 450 rpm compared to 300 rpm. Deposits of manure did not give a uniform increase as the speeds increases. Figures 3 and 4 showed the effect of disc speeds and heights of flow mechanism on spreading uniformity for the modified spreader. It gave a more uniform distribution pattern at disc speed of 300 rpm, followed by 150 rpm and least uniformity at 450 rpm as shown in Figure 3, the three distribution pattern agreed with the result obtained by (Lary and Allan, 2012) as what they refered to as normal spread distribution. Highest deposit of amount of manure 2.69 kg was seen at disc speed of 450 rpm and reduced with decrease in the disc speed.

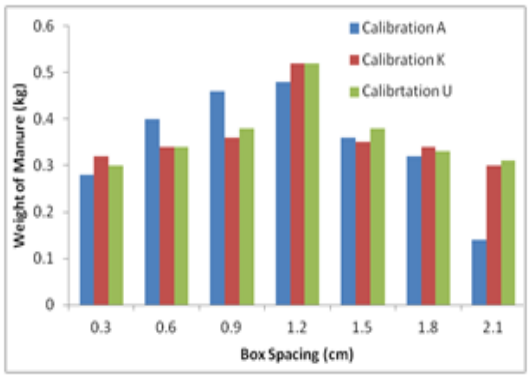

Fig 1: Effect of Height of Flow on Manure Spread Uniformity for the imported spreader

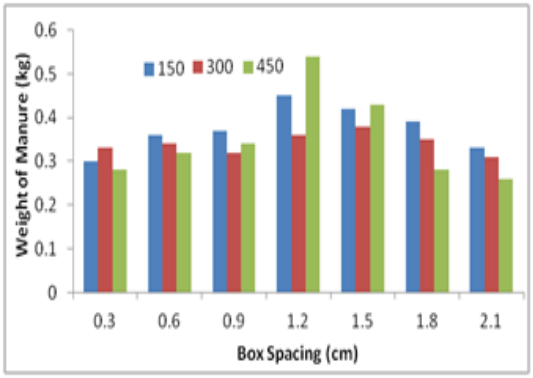

Fig 2: Effect of Disc Speed on Manure Spread Uniformity for imported spreader

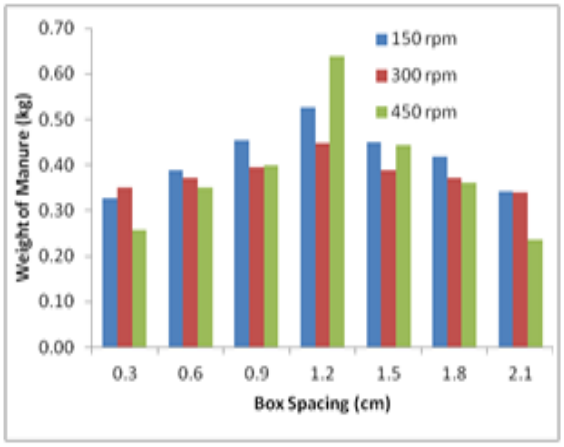

Fig 3: Effect of Disc Speed on Uniformity of Manure Spread for modified spreader

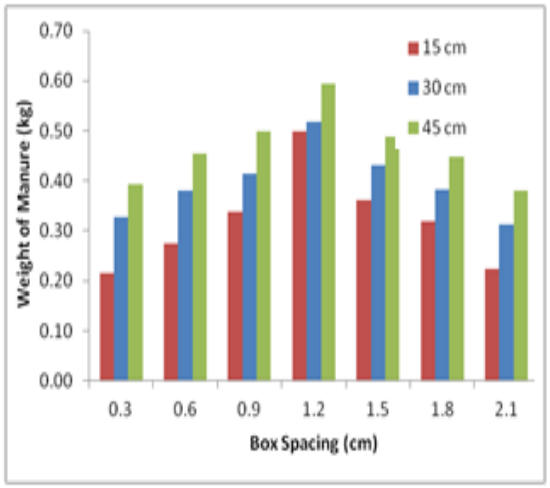

Fig 4: Effect of Height of Flow on Uniformity of Manure Spread for modified spreader

This might be attributed to less disc speed which leads to less deposit of manure per unit area. The effect of height of flow mechanism on uniformity of manure distribution showed a better pattern at 30 cm and 45 cm compared to 15 cm (Figure 4). Highest deposit of amount of manure 3.26 kg was noticed at 45 cm height of flow mechanism and decreased as height decreased. This might have occured due to increase in the openning of the flow mechanism. In Comparing the performance of the imported manure spreader with the modified spreader (Fig 2 and Fig 4) respectively. Figure 4 gave a better graphical understanding of how weight of manure is been uniformly deposited in respect to height of flow mechanism and this agreed with the result obtained by (Lary and Allan, 2012) and refered to as normal spread distribution. As the height of flow mechanism increased the amount of manure deposited per unit area also increased.

Spreading Uniformity of Spreader: Table 2 shows how the manure was distributed in weight per box. A better uniform distribution was recorded at 300 rpm followed by 150 rpm.

This indicates decrease in disc rpm speeds increases uniformity of spreading. Also an increase in height of flow mechanism increases the quantity of manure deposited. This may be attributed to the increase in manure discharge as the speed increased. There was statistical difference at all the levels of speed and for heights of 30 and 45 cm were statistically the same and both different with 15 cm height of flow mechanism.

Table 2: Effect of Disc Speed and Height of Flow on Spread Capacity

Treatment	Spread Capacity (kg/hr)
Speed (rpm)	
150	1469.4c
300	2426.6b
450	3663.2a
SE±	73.875
Height of Flow (cm)	
15	2185.1b
30	2639.2a
45	2734.9a
SE±	73.875

**= Significant at (P≤0.05) s followed by the same letter(s) in the column are not different statistically at P=0.05 using DMRT.*

Conclusion: The spreader was evaluated using cow dung at 11.17% MC, three disc speeds of S1 (150 rpm), S2 (300 rpm) and S3 (450 rpm), three heights of flow mechanism of (15 cm), (30 cm) and (45 cm) and a tractor forward speed of 8.2 km/hr. Optimum effective field capacity determined was 9.8 ha/hr at 450 rpm and 45 cm height. The spreader also recorded the best application rate of 4082.1 kg/ha compared to the imported spreaderof 1875.3 kg/ha and swath width of 9.0 m compared to 9.5 m of the imported with better uniform distribution.

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