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RESEARCH ARTICLE

Calibration and Performance of Tractor Mounted Rotary Fertilizer Spreader

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Abstract

The study aimed to test tractor mounted rotary disc fertilizer spreader with two ground speeds in order to obtain higher field capacity with required spreading uniformity. The spreader was calibrated at a rate of 250 Kg Urea ha^{-1}. Spreader was calibrated by using weighed amount of fertilizer in hopper and re-weighing remaining amount after running spreader over test strip of known area. Spreader was tested over area of 1000 m^2 for its performance at two different ground speeds. At 4.23 km hr^{-1}ground speed, with fertilizer application rate of 250 kg ha^{-1}, effective field capacity was 2.78 ha hr^{-1} with field efficiency of 71.28%, fuel consumption of 1.11 Liters ha^{-1} and CV of fertilizer samples was 20.82%.While at 8 km hr^{-1}ground speed with fertilizer rate of 250 kg ha^{-1} field capacity was measured as 5.33 ha $hr^{-1}$with field efficiency 73.11% and a fuel consumption of 1.64 Liters ha^{-1} with 21.73% CV of fertilizer samples. Data were analyzed using Gnumeric 1.12 software .Aspect ratio of fertilizer samples revealed almost same quantity of fertilizer spread on left and right from the center of swath. This study concludes that there is no significant effect of ground speed on spreading uniformity of rotary disc spreaders. Spreaders should be operated at higher ground speeds to achieve higher field capacities.

INTRODUCTION

Soil contains various micro and macro elements which are essential for plant growth and yield. It is necessary to save important nutrient elements like nitrogen, phosphorus and potassium by application of chemical fertilizers. Especially in poor soils need fertilizing application to save main elements for increasing yield and quality of crops. Granular fertilizers and seeds can be applied to the field with spreaders to save the time and cost [1]. Fertilization practice is one of the most important operations in agricultural production. Indeed, this task is necessary to apply nutrients satisfying the demands of the plants according to yield objectives. To carry out inputs application, centrifugal spreaders are very popular due to their low cost and simplicity of use [2].

Calibration of spreaders before using in field is very important. Calibration is to set the spreader on a setting on which spreader can give a required quantity of fertilizer over an area. At each cropping season the spreader should calibrated according to the type of fertilizer used and field conditions [3]. One common method of application is broadcast applications, which simply means that the fertilizer is spread uniformly over the surface of the soil. For certain situations broadcast applications can be an inefficient method of application because there is much greater soil to fertilizer contact in more fixation or tie-up of nutrient. The majority of fertilizer in advanced countries of the world (85%) is distributed by fertilizer spreader machines [4]. Balanced use of fertilizers increase the yields of wheat by 77%, sugarcane 100%, rice 25-100% and cotton by 400%. To reap the benefits of balanced use of fertilizers, our farmers must implement the five key practices (a) apply only those nutrients that will result in economic yield increases (b) apply appropriate nutrient rates (c) apply appropriate sources of fertilizer nutrients (d) apply nutrients at appropriate timing (e) apply using the most effective and practical application techniques [5].In ground-based application predominantly spinner disc spreaders are used. Spinner type spreaders are attractive because they can cover large areas effectively; they are simple in design, reliable, inexpensive, robust, and require little maintenance [6]. It is mandatory to mechanize our agriculture to feed ever increasing population of our country. Manual application of chemical fertilizer is proved inefficient and time consuming.

MATERIALS AND METHODS

The field experiments were conducted on Latif Experimental Farm of Sindh Agriculture University Tandojam, Sindh Pakistan during February 2012. The experiments were conducted over a field prepared for wheat sowing. In this study FIAT-460 diesel tractor and a twin disc mounted type rotary fertilizer spreader was used.

Operating ground speed

Operating ground speed (S) of the tractor was measured from the time required for the tractor to travel the distance of 20 m between two poles fixed in the test plot. Three average readings were taken during low and high ground speed respectively.

Effective and total width of swath

Effective width (WE) of the fertilizer spreader was measured by placing collection trays 0.5m × 0.5m in a row 0.5 m apart from each other perpendicular to the direction of travel according to the ASAE 341.2 standardized collection tray method as described by [7,8]. Total width (WT) was considered with few fertilizer grains in outer collection trays Fig.1. Both widths were calculated by average of the three values.

Calibration of spreader

Spreader was calibrated by field method in order to calibrate the spreader the hoper was filled with 15 Kg Urea fertilizer (Engro Chemical with particle size 1 to 2 mm) the machine was operated on the ground in 1^{st} high gear forward speed of 4.23 km hr^{-1} with spreader openings of 5.8 cm ×11 cm. A test strip of 93 m^2 [9] was selected in the middle of field and divided with effective width of spreader 9.12 m to calculate test length of 10.13 m. After running spreader over test strip, the remaining amount of fertilizer in the hopper was re-weighed to calculate the amount of fertilizer distributed over 93 m^2. Procedure was repeated several times with reduced openings to achieve required application rate of fertilizer 250 $kgha^{-1}$ Table No.1. After calibration the spreader at this speed and rate, was tested over an area of $1000m^2$. All required data was noted. Then spreader was again calibrated at higher forward speed of 8 km hr^{-1} with almost same fertilizer application rate of 240 kg ha^{-1} and again tested at this speed for its performance. During the calibration and performance test the ground speed was determined by fixing two poles on the ground 20 m apart. The time to pass the tractor through the poles was measured by stop watch. Three average readings were used to calculate the ground speed. Calibration and performance test were conducted at 400 RPM of P.T.O of tractor. During the test wind velocity was considered which was negligible hence assuming no effect on fertilizer spreading pattern. Height of the spreader from the ground was 1.28 m.

Field capacity and efficiency of spreader

Effective field capacity (EFC) of the spreader was calculated in ha h^{-1} using [10] formula considering 70% efficiency using effective width of the spreader (9.12 m) (Table 2) in this table average of three readings are given. Theoretical field capacity (TFC) was calculated using full width of the machine (9.24m) as shown in table (Table 3). While field efficiency (FE) is the ratio of effective to theoretical field capacity.

Fuel consumption

Fuel consumed by tractor during the test was separately measured for both speeds in L ha^{-1}. Before conducting the test fuel tank of tractor was filled at full capacity and after the test it was refilled with fuel by graduated cylinder to calculate the quantity of fuel consumed per hectare.

Fertilizer spreading pattern and uniformity

The spreading pattern is defined as the fertilizer's distribution at right angles to the driving direction in one single pass. Spreading pattern was observed. Spreading uniformity refers to deviations in application rate between two or more selected areas where the fertilizer has been spread. Spreading uniformity was determined by placing a row of collection trays (0.5 m x 0.5 m), 0.5 m apart from each other at right angles to the direction of travel Fig.2. Space was provided between the trays from where drive wheels of the tractor passed. However during one pass the fertilizer speeded over ten collection trays. Fertilizer from each collection tray was collected and placed in polythene bags and labeled. The samples were immediately weighed over digital scale. The measure of dispersion for evaluation of distribution pattern and uniformity was calculated using the formulae given by [11] as follows and Gnumeric 1.12 Software was used for data analysis.

Mean absolute deviation

Mean absolute deviation of collected fertilizer samples was calculated with following formula;

$$la = \frac{1}{n}\sum_{i=1}^{n}|x_i - \bar{x}|$$

Where,
la= Mean absolute deviation
n = Number of observations
x_i = Value of an individual observation
$\bar{x}$= Mean value of all observations.

Mean squared deviation and standard deviation

Mean squared deviation and standard deviation of sample were calculated by the formulae;

$$\sigma^2 = \frac{1}{n}\sum_{i=1}^{n}(x_i - \bar{x})^2$$

Where;
σ^2 = Mean squared deviation

n = Number of observations
x_i= Value of an individual observation
$\bar{x}$ = Mean value of all observations

By obtaining the root of the variance it is possible to obtain the standard deviation (s).

$$S = \sqrt{\sigma^2}$$

S = Standard deviation

Coefficient of variation

The coefficient of variation is a relative measure of dispersion that gives the standard deviation as a percentage of the mean value,

$$CV\ \% = \frac{100 \times S}{\bar{x}}$$

Where;
CV = Coefficient of variation
S = Standard deviation
$\bar{x}$ = Mean value of all observations

Aspect ratio

The aspect ratio gives the proportion of the totally collected amount of granules dispersed during the tests to the left and to the right from the center of swath. Ten samples were observed and collected from single pass; all samples were placed in polythene bags and weighed individually by digital scale. The aspect ratio on left and right was calculated as follow;

$$AR_l\ (\%) = \frac{M_1}{M} \times 100$$

$$AR_r\ (\%) = \frac{M_2}{M} \times 100$$

Where;
AR = Aspect ratio, left (l) and right (r)
M_1 = Sum of observations on left side
M_2 = Sum of observations on right side
M = Sum of all observations

RESULTS AND DISCUSSION

Average operating ground speed during the test was measured as 4.23 and 8.00 km hr^{-1}during 1st high and 4th low gear speed of the tractor respectively which is with the agreement of [12] recommend forward ground speed of 5 to 8 km hr^{-1} for rotary disc spreading machines. At both ground speeds spreader was calibrated separately on required fertilizer application of rate of 250 Kg ha^{-1} which is the requirement of nitrogen of wheat crop per hectare [13] table 1 shows the result of calibration on both ground speeds.

Field capacity was recorded as 2.78 and 5.33 ha hr^{-1} with ground speeds of 4.23 and 8 Km hr^{-1} respectively which is with the agreement of [14] Table 2 shows the effective field capacity of spreader during both speeds.

Field efficiency of the spreader is the ratio of effective to theoretical field capacity; it was calculated as 71.28 and 72.12 % with ground speeds of 4.23 and 8 Km hr-1 respectively. Field efficiency of spreader calculated is with the agreement of [15] table 3 shows the calculation of theoretical field capacity of spreader during both ground speeds.

The fuel consumed by the tractor was measured 1.11 and 1.60 Liters ha $^{-1}$ during the ground speed of 4.23 and 8 Km hr^{-1} respectively for single pass of fertilizer. Hence fuel consumption also increased with increase of ground speed of tractor.

Application accuracy is an important property to assess the fertilizer application system. CV is typically used to evaluate the quality of spread pattern. If the CV is lower means distribution pattern is more uniform. Statistical analysis of the weight of the samples collected was done standard deviation and coefficient of variation was measured 5.18 and 20.82 at ground speed of 4.23 Km $hr^{-1}$and 5.28 and 21.73 with the ground speed of 8 Km hr^{-1} respectively table (4,5) show the weight of fertilizer samples collected from collection trays and the calculations of SD and CV.

The results of spreading uniformity are with the agreement of [16] who conducted study on granular spreaders they reported a CV from 10 to 25 %, hence the results of spreading uniformity are comparable with the previous work done on the spreaders.

The aspect ratio was calculated to observe the amount of fertilizer distributed at right and left side from the center of swath. During low ground speed of 4.23 Km hr-1 the aspect ratio on right AR_r was 50.2% and aspect ratio at left AR_l was 49.8% as shown in table 6. While during the high ground speed 8 Km hr-1 AR_r was 51.02% and AR_l was 48.98% as shown in table 7.

During both speeds aspect ratio shows almost same quantity of fertilizer spread on left and right. But the spreader was spreading a little quantity of fertilizer greater on right side from the center of swath. The reason for that was a little wear in the spreader side link pins so spreader was a little tilted on right side instead mounted flat position.
At ground speed of 4.23 Km hr^{-1} the field capacity was measured 2.78 ha hr^{-1} with 71.28% field efficiency and good spreading uniformity CV= 20.82. With 89% increase in ground speed 91% increased field capacity was observed with 1.17% more field efficiency with no significant effect on spreading uniformity CV=21.73. While 45% increase in fuel consumption was recorded.

Table 1.Calibration of spreader at two different speeds

Sr. No.	Speed (Km hr^{-1})	Openings of Spreader (cm × cm)	Effective Width (m)	Initial Weight of Fertilizer (Kg)	Final Weight of Fertilizer (Kg)	Fertilizer Used (Kg/93m^2)	Fertilizer Rate (Kg ha^{-1})
1	4.23	5.8×0.5	9.18	15	12.67	2.32	250
2	8.00	5.8×1.5	9.18	15	12.67	2.32	250

Length of test strip =10.13 m

Table 2. Effective field capacity of spreader at two different speeds, average values are given

Sr. No.	Distance Travelled (m)	Time Taken (Seconds)	Speed (Km hr^{-1})	Effective Width (m)	EFC= $\frac{0.7 \times S \times W}{10}$
1	20	17.00	4.23	9.12	2.78
2	20	8.00	8.00	9.12	5.33

Table 3.Theoretical field capacity of the spreader at two different speeds average values are given

Sr .No.	Distance Travelled (m)	Time Taken (Seconds)	Speed (Km hr^{-1})	Full Width (m)	TFC= width (m) × speed (km h^{-1}) ×0.1
1	20	17.00	4.23	9.24	3.90
2	20	9.00	8.00	9.24	7.39

Table 4. Statistical analysis for spreading uniformity of the samples of fertilizer collected with ground speed of 4.23 Km hr^{-1}

x	$x_{i\,(gm)}$	$x_i - \bar{x}$	$\lvert x_i - \bar{x} \rvert$	$(x_i - \bar{x})^2$
1	18.00	-7.00	7.00	49.00
2	21.00	-4.00	4.00	16.00
3	24.00	-1.00	1.00	1.00
4	26.00	1.00	1.00	1.00
5	31.00	6.00	6.00	36.00
6	33.00	8.00	8.00	64.00
7	29.00	4.00	4.00	16.00
8	27.00	2.00	2.00	4.00
9	24.00	-1.00	1.00	1.00
10	16.00	-9.00	9.00	81.00
∑	**249.00**	**-1.00**	**43.00**	**269.00**

Mean value of all observations ($\bar{x}$) = 24.9
Mean Absolute Deviation (la) = 4.3
Variance (σ^2) = 26.9
Standard Deviation (S) = 5.18
Coefficient of Variation (CV) = 20.82%

Table 5. Statistical analysis for spreading uniformity of the samples of fertilizer collected with ground speed of 8 Km hr-1

x	$x_{i\,(gm)}$	$x_i - \bar{x}$	$\lvert x_i - \bar{x} \rvert$	$(x_i - \bar{x})^2$
1	16.00	-9.00	9.00	81.00
2	22.00	-3.00	3.00	9.00
3	24.00	-1.00	1.00	1.00
4	27.00	2.00	2.00	4.00
5	31.00	6.00	6.00	36.00
6	32.00	7.00	7.00	49.00
7	28.00	3.00	3.00	9.00
8	25.00	0.00	0.00	0.00
9	22.00	-3.00	3.00	9.00
10	16.00	-9.00	9.00	81.00
$\sum$	**243.00**	**-7.00**	**43.00**	**279.00**

Mean value of all observations ($\bar{x}$) = 24.3
Mean Absolute Deviation (la) = 4.3
Variance (σ^2) = 27.9
Standard Deviation (S) = 5.28
Coefficient of Variation (CV) = 21.73 %

Table 6.Aspect ratio of samples of fertilizer collected with ground speed of 4.23 Km hr^{-1}

Sr.No.	Weight of samples at right side from the center of swath (gm.)	Weight of samples at right side from the center of swath. (gm.)	Aspect ratio right $AR_l\ (\%) = \frac{M_1}{M} \times 100$	Aspect ratio left $AR_r\ (\%) = \frac{M_2}{M} \times 100$
1	33	18	49.8	50.2
2	27	22		
3	26	24		
4	22	28		
5	17	32		
Total	125 (M_1)	124 (M_2)		

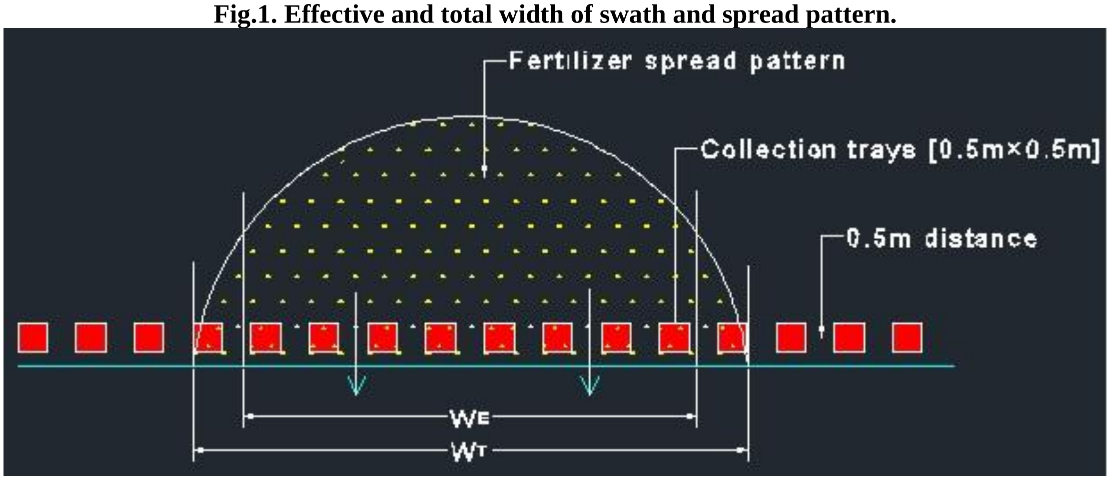
The sum of total weight of all samples (M) = 249gm

Table 7. Aspect ratio of samples of fertilizer with ground speed of 8 Km hr^{-1}

Sr.No.	Weight of samples at right side from the center of swath (gm.)	Weight of samples at right side from the center of swath. (gm.)	Aspect ratio right $AR_l\ (\%) = \frac{M_1}{M} \times 100$	Aspect ratio left $AR_r\ (\%) = \frac{M_2}{M} \times 100$
1	33	17	48.98	51.02
2	27	22		
3	25	23		
4	21	26		
5	18	31		
Total	124 (M_1)	119 (M_2)		

The sum of total weight of all samples (M) = 243gm

Fig.1. Effective and total width of swath and spread pattern.



CONCLUSION

In this study it can be concluded that rotary disc fertilizer spreader can be operated at higher ground speeds depending upon field conditions. However the ground speed has no significant effect on fertilizer spreading uniformity. Spreaders should be operated with higher field capacity and field efficiency with appropriate increase of fuel consumption of tractor. Spreaders can be calibrated by field method over a small test area.

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