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Methodology to Evaluate the Fertilizer Distribution by Helical Doser from Seed Planter

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

This article aims to develop a precision methodology, to evaluate the work of a helical doser from a seed planter. The experiment was carried out in two conditions, a bench in laboratory, and, in a seed planter in the field, comparing the proposed evaluation methodology in the laboratory, linear methodology (LM), against the ISO 5690/2 (1984) method. In the laboratory's test, it was tested: 0°, +11° and -11° slope of doser. In LM, it was used a metal gutter with 125 polyethylene collectors, both placed next to the other. In the field, it was used only LM, and for such two doses were tested, 250 and 440kg ha^{-1}. The variation coefficient (VC) in the LM, the 0º condition performed with the best dosage, varying from 10.15% to 13.76%, against 13.95% to 17.84% in the + 11° slope and 11.86% to 13.79% in the -11º. The VC compared in ISO 5690/2 method shows a very different

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result, indicating variations from 0.7 to 2.3%, which is 88% smaller than LM. In field, the VC increased to 25.70% to 40.96%. Comparing the VC of ISO 5690/2 with the field test, the differences are even bigger, 2.3% compared to 40.96%. The LM presents concise data to clearly observe variations in the working conditions of the fertilizer helical doser.

Keywords: Precision; variation coefficient; slope; ISO 5690/2.

1. INTRODUCTION

The expansion and dissemination of agricultural technologies, combined with the need to increase production without expanding the area, the drilling process becomes a fundamental factor of success of any agricultural crop. In this operation is necessary to dose and distribute the seed and fertilizer accurately, in this context, has been common to find out in the field, a heterogeneity of the culture in spatial arrangement and in the distribution of fertilizers, which will imply in uniform plants along the sowing line.

According to Food and Agriculture Organization [1], with a successive growth in 2019 of the global nutrients ($N+P_2O_5+K_2O$) consumption, it is expected to reach 199.1 million tones. In Brazil, the consumption in 2017 was 34.4 million tons of fertilizers, of which 76.5% was imported [2], which emphasizes the need to use this input efficiently to guarantee results in accordance with the investment. Fertilizer feeders are mechanisms coupled to row seed planter, being responsible to depositing the fertilizer in the soil uniformly according to a defined dosage. Failures in dosage can lead to waste of fertilizers, occurring excess of fertilizer in some plants and lack in others, resulting in low potential development of the plants, decreasing the yield. In order to evaluate the fertilizer distribution, is necessary to follow a methodology, and in this sense, there is no standard method in Brazil to evaluate the performance in field, like there is to seed distribution established by ABNT [3], which sets the form of laboratory and field tests, evaluating the regularity of seed distribution in row seeders. Currently, the researches in Brazil and in the world are mostly in laboratory tests, which can provide indications about the performance of the feeder, and simulate different work situations such as slopes and doses, however, it doesn't consider other factors relating to mechanics and stationary, as well as the actual field conditions and dosage. ISO 5690/2 [4] standard is available, which standardizes tests with fertilizer distributors, but doesn't present data accurately, considering only laboratory tests and may result in dubious data.

The fertilizers feeders used in row seed planters in Brazil are helical feeders, the dosage by this system is given by the rotational movement of helical screw, where the material to be transported, fills the space between the screw, being displaced from the reservoir to the conducting tube, the dose is regulated by relation which drives axis of the helicoid [5]. This mechanism is found in the seed planter market in three models: helical screw feeders by gravity, overflow longitudinally or lateral. The parameter that best qualifies the work of the helical feeders is the coefficient of variation [5,6,7,8,4,9] which indicates the percentage of irregularity of a certain variable observed, so the lower the value, the better the performance of the mechanism.

In laboratory conditions, the distribution can reach variation coefficient between 9.7 and 13.2% [7,9], and in the field, in real working conditions, reaching values close to 35%, considering the most efficient feeders available on the Brazilian market, by overflow longitudinally, in gravity helical feed, it can reach up to 79% [10]. Such difference, are related by the discrepancies between field tests, laboratory and methodologies. Among the factors influencing the fertilizer dosage, longitudinal work slope is the most significant, since it is constantly tested in experiments, pointing to greater variations as a function of positive slopes [5,11,12], that is, the direction in which the distribution occurs against the direction of gravity. These variations are correlated with pulse that exist in helical screw feeder by gravity, which upon completion of a cycle called the "cycle", the thread discharges at a higher speed than loading, resulting in a "failure" of dosage, factors that according to Rosa et al. [10] in the overflow dispenser are less intense than in the helical screw by gravity. Based on this information, the fertilizer feeders have a condition in which their performance is optimized or impaired, but for that, the evaluation methodology should be as close as possible to the real working conditions. In this sense, the objective of this work is to propose a methodology of field and laboratory to evaluation of fertilizer feeders from seed planters.

2. MATERIALS AND METHODS

The study was carried out in two parts in 2016, one in the agricultural research area and another one in the laboratory, both in Nucleus of Studies in Soils and Agricultural Machinery (NESMA) of the Federal Institute of Education Science and Technology of Rio Grande do Sul Campus Sertão, in Sertão (RS), Brazil. In the laboratory experiment it was used a bench of fertilizer feed (Fig. 1D), equipped with tilt adjustments in the longitudinal and transverse directions. At the bottom of this, there was a rubber mat driven by an induction engine with a constant velocity of 0.42 m s^{-1}. The bench feeders were power by a 0.73 kW electric engine, combined with a motor reduction system controlled by a WEG® brand programmable logic controller (CLP). The doser used for the test was a helical screw by overflow longitudinally working at a rotation of 60 rpm.

To collect the fertilizer, a metal gutter with dimensions of 0.1 x 12.5 x 0.1 m was used in which 125 polyethylene (Fig. 1D) collector containers with dimensions of 0.1 x 0.1 m were placed, one next to the other, with no space between them.

The test was performed as follows:

- i: A gutter with collecting pots was arranged on the mat (Fig. 1D), being filled with pots;
- ii: The bench is activated for 300 seconds, aiming to equalize the flow of fertilizer by the doser;
- iii: With the flow stabilized, the flow of fertilizer is released to the gutter that moves according to the speed of the conveyor, simulating the linear field displacement;
- iv: After passage of the gutter, each collecting pot is withdrawn in the sequence arranged in the gutter and the mass deposited is measured;
- v: Process the data, quantifying the evaluation parameters.

The execution of the experiments, the granulometric characterization of the tested fertilizer (Table 1) was carried out, framed between granulate and granules mixture. The formulation used was NPK 2-28-20, with density of 1.17 g cm^{-3} and humidity of 4.1%.
The field test (Fig. 1E), the evaluation methodology was as follows:

- i: Drill at least 100 meters an area to stabilize the fertilizer flow;
- ii: Placed under the ground the gutter (same described above), it in the center of the path of the seed drill (Fig. 1E);
- iii: Performs the test by placing the doser tube moving just above the gutter, here is used of a cart (Fig. 1F).
- iv: The fertilizer sample is withdrawn from each collecting pot, packaged in bags, identified according to the pot sequence;
- v: In the laboratory, the mass of each sample is measured, and the evaluation parameters are calculated.

To improve the performance of the test, a wheel was delimit from the depth of the sowing line to widen the space between the gutter and the sowing lines. At the beginning of the test, the tractor was positioned in the plot and then the collector gutter was directed in front of the tractor-seeder assembly. In the test, two dosages were used: 250kg ha^{-1} and 440kg ha^{-1}, with 4 replicates at each dose. The coefficient of linear variation of the fertilizer was also evaluated, as well as generation of dosage graphs as a function of space. The machine used in test was a drill from Semeato ®, SHM15/17 model with 7 row (45 cm), and a New Holland® tractor, TL95E model with 95cv of power.

As an evaluating parameter, the coefficient of variation of the linear distribution obtained in the tests was used. The data were tabulated in a spreadsheet, after which they were submitted to the statistical evaluation that included a descriptive analysis, test of variance, and comparison of means by Test t at the level of 5% of probability, all performed by Assitat 7.7 beta [13].

Table 1. Fertilizer granulometry used in bench test (%)

Repetition	4 mm		2 mm		0.5 mm	
	Flow	Retention	Flow	Retention	Flow	Retention
1	93.5	6.5	13.0	87.0	0	100
2	95.1	4.9	10.6	89.4	0	100
3	93.3	6.7	12.3	87.7	0	100
4	92.9	7.1	12.7	87.3	0	100
Average	93.7	6.3	12.15	87.85	0	100

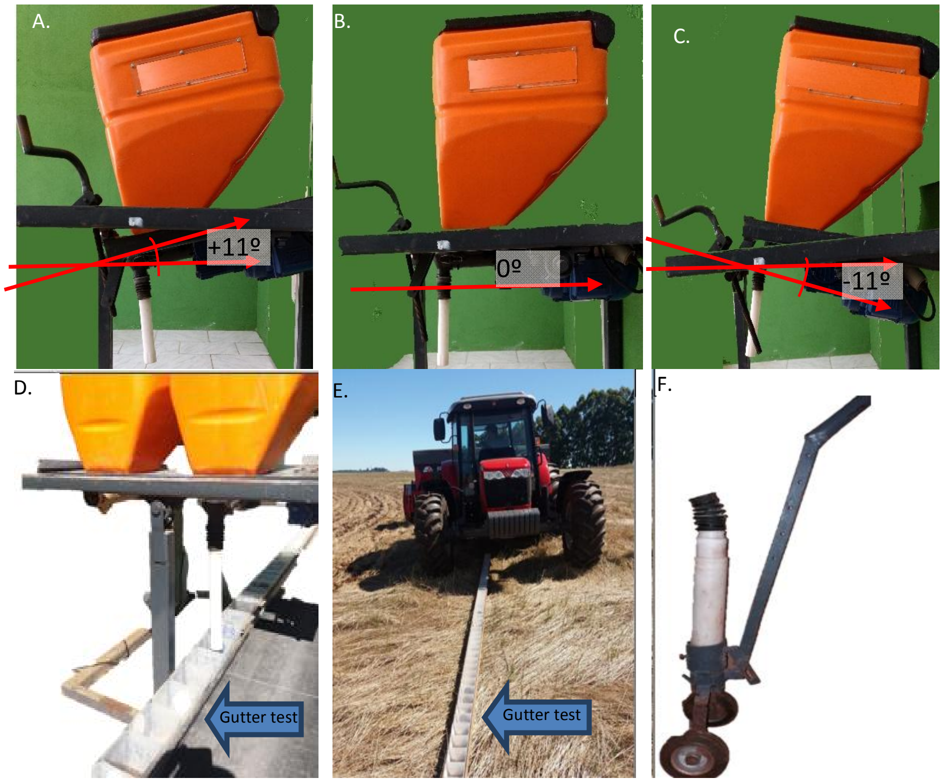

Fig. 1. Illustration of doser test in +11º (A), 0º (B), -11° (C) in laboratory condition, carried out in bench test (D), field test (E) and Driver's cart (F)

3. RESULTS AND DISCUSSION

The variation coefficient (VC) obtained by linear methodology (Table 2) various conformed angle tested, the best was 0º condition, showing variation from 10.15% to 13.76%, against 13.95% to 17.84% in + 11° slope and, 11.86% to 13.79% in the -11°. This fact demonstrates that the greater variations occurred in the positive slope, which the doser is with the outlet nozzle at a higher position that the inlet position of the fertilizer, in this sense, the dosing occurs in a manner contrary to flow of overflow barrier. In bench test, [10] it was found the same situation, however the slope was 0º, -20° and +20º, in this work, the more variation occurred in + 20º with an NPK fertilizer of average granulometry. The tests with 7 helical doser [9], the authors founded a large difference between the fertilizer metering devices marketed and those evaluated under the longitudinal gradients test, the difference between dosages was more important in the +5 and +15° slope.

Table 2. Variation coefficient in linear distribution of the fertilizer in the different longitudinal slope and repetitions of the linear and ISO 5690/2 (1984) methodologies (%)

Repetition	Linear methodology			ISO 5690/2 (1984)		
	0°	+ 11°	- 11°	0°	+ 11°	- 11°
1	10.15	13.95	12.71	1.32	1.87	1.01
2	10.75	14.13	13.38	1.07	1.41	1.82
3	13.12	15.80	13.70	0.92	2.30	1.00
4	12.26	15.15	13.79	1.03	1.50	1.17
5	13.76	17.84	11.86	0.70	1.50	1.58
Average	12.01B	15.38A	13.09B	1.01B	1.72A	1.32 AB

** Averages followed by the same capital letter did not differ statistically from each other, by the Tukey test ($p<0.05$).*

The variation coefficient obtained by ISO 5690/2 [4] shows very different values from the linear methodology, indicating variations from 0.7 to 2.3%, which is 88% smaller than the proposed methodology. ISO 5690/2 [4] is based on the collection fertilizer in 30 seconds, if simulate the speed 4, 5 and 6 km h^{-1}, commonly used in crop sowing, will represent 33.33, 41.67 and 50 m of displacement over this period, so we would have several oscillations of dosage. In Fig. 2, a graph with the linear distribution of fertilizer along the route was assembled with the data of the proposed linear methodology, which clearly visualizes the variations and the effect of the inclination in the fertilizer flow, in which the lower variation in 0ºslope, and bigger in 11º, corroborating with the VC (%) of Table 2.

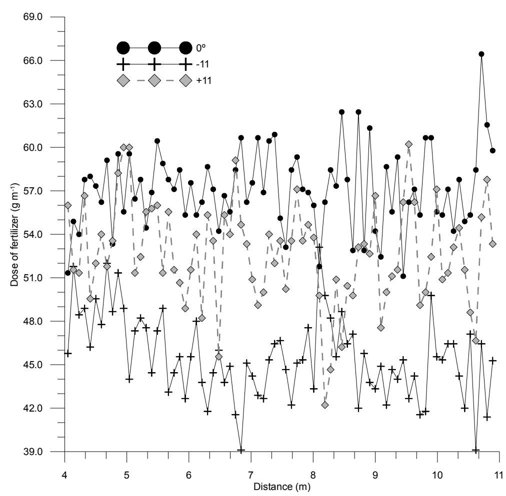

Fig. 2. Linear distribution of the fertilizer in slope condition 0°, - 11° and + 11° using linear methodology in laboratory condition (g m^{-1})

Each point of the graph (Fig. 2) represents a sample collected and measured the mass as a function of the position in space, to improve the data, the initial samples were taken, the first 4 m of displacement, and the bench was operated for 300 seconds to stabilize the flow of fertilizer in the doser. In the level condition, the flow is little more uniform; the difference between the doses in each meter is smaller than the other conditions, save some isolated peaks that must be referring to the fertilizer accommodation inside the body of doser. The worst condition was to + 11º, which in addition to reducing the dose, corroborating with [12]. Additionally of this, [2] comment that independent of type of fertilizer our dosage used, the VC (%) remains high, pointing to a cyclical behavior of the dosage, where the mean dosage remains close to the established dose, and the high VC is a consequence of amplitude peaks. Here, the results shows in all the slopes tested, variations occur in the dosage as a function of longitudinal slope, corroborating with the research [14], who state that even with the use of a helical doser by overflow, higher doses, or drive speeds performance is improved.

Field methodology, the VC (%) presented between 10.15% and 17.84% in the linear methodology (Table 2), increased to 25.70% at 40.96% (Table 3), it represents an increased at least 50%, pointing to the field influencers among them the irregularity of the terrain, the trepidation of the sowing system (conduit and furrow, fertilizer deposit) and skating of the whole. Comparing the VC (%) of ISO 5690/2 [4] with from field test, the differences are even greater, 2.3% against 40.96%, considering the 250 kg ha^{-1} of dosage, the variation will be until 352,4 kg ha^{-1} in linear methodology, and in ISO 5690 [4], it will be 255,75 kg ha^{-1}, this results in serious damages, since in high doses in soil, and missed fertilizer in farm, since that dose is lower.

Table 3. Variation coefficient of the linear distribution of the fertilizer collected in the field with different doses (%)

Repetition	Dose (kg ha^{-1})	
	250	**440**
1	38.78	29.76
2	39.47	26.32
3	40.96	25.70
4	38.09	31.23
Average	39.32	28.25

The mechanism working in higher dose, the rotation of the thread is larger, consequently, there is more turns, occurring more pulses, but very close to each other, covering in this effect, reducing the VC (%). According to Bica and Souza [14], the mass measured by the helical fertilizer dosing mechanisms varies with the change in the drive speed and the screw pitch of the helicoid, adding to these, [9] state that greater variation of the volume measured is cause by the longitudinal inclinations, presenting in some cases errors impermissible from the point of view of engineering and fertility. This amplitude in the longitudinal distribution, as shown in Fig. 2, leads to heterogeneity of soil fertility, which is observed in the linear methodology and not visible by the data shown by ISO 5690/2 [4]. When the soil has high natural fertility, with soil profile constructed, this difference will not be clearly observed in the plant, however in poor soils, and this variation can be visualized due to the lack of uniformity of the amount of nutrients applied. Fertilizer overdoses are detrimental to the environment, and under dose represents a waste of energy and investment [15].

The linear distribution of fertilizer in field working conditions (Fig. 3) shows a smaller amplitude at the points in dose 450 kg ha^{-1}, demonstrated a higher concentration of points in a given range from 1.7 a 1.9 g, against 0.7 to 1.1 g from dose 250 kg ha^{-1}, thus reducing the variation coefficient. The comportment of linear distribution in both doses, is possible verify higher peaks equidistant, demonstrating the pulse of doser, it is the most characteristic of helical thread.

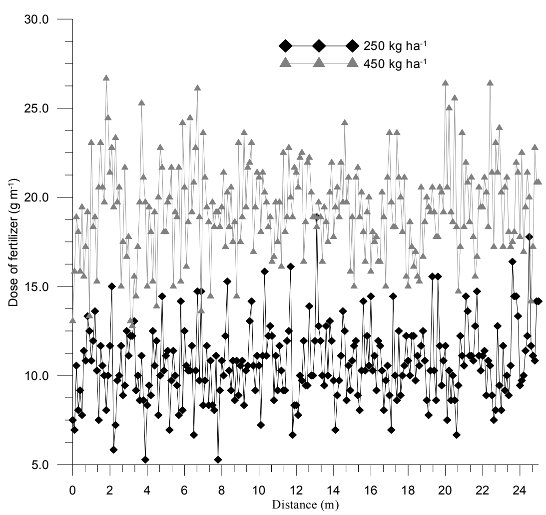

Fig. 3. Linear distribution of fertilizer by the helical doser by overflow obtained in the linear evaluation methodology (g m^{-1})

Considering the VC (%) as an indicator and comparing the two methodologies, there is a greater variability between the data, it's in agreement with [16], which in field tests with the same type of doser, employing the same methodology, found higher variation coefficient than those found in the literature, which did in laboratory conditions. This research, cited the factors that not only the dosing mechanism, but the external elements to this, trepidation of the set tractor-seeder, irregularities of the terrain, bumps, irregularities of speed, conditions these not present in stationary tests in laboratory. In field conditions, it is clear that the amplitude is increased, which directly leads to an increase in the VC (%) of the distribution.

4. CONCLUSION

The proposed methodology presents concise data, so that it is possible to clearly observe variations in the working conditions of the fertilizer helical doser, with spatial precision of the dosage. The actual working conditions of a tractor/drill assembly are preferable for the more reliable measurement of a dosing device that has generated data more consistent with how is applied the fertilizer in the soil and how it is distributed for crop development.

The linear evaluation methodology estimates a greater variation coefficient, pointing to the field influences, and in the laboratory methodology tested by ISO 5690/2 method estimates a CV (%) with variations of 0.7 to 2.3%, against 10.15% to 17.84% in the linear methodology in the laboratory, and 39% of the linear methodology to the field, performed with granulated fertilizer.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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