

**PERFORMANCE OF FERTILIZER METERING MECHANISMS OF PLANTERS AS A
FUNCTION OF LONGITUDINAL INCLINATION**

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ABSTRACT: Sowing occurs in agricultural areas with irregular relief, influencing the quality of seed and fertilizer distribution. The aim of this study was to analyze the performance of different fertilizer metering mechanisms of planters as a function of longitudinal inclination. The experimental design was a completely randomized design with five treatments and six replications. Treatments consisted of five longitudinal inclinations to the metering mechanism (−10, −5, 0, 5, and 10 degrees). The mass of fertilizer collected per minute was considered as a replication. We worked with two types of fertilizers: a mixture of granules and powder. Metering mechanisms used were a horizontal toothed rotor, helical without flow restrictor, helical with lateral overflow, and helical with longitudinal overflow. The longitudinal inclination of $\pm 10^\circ$ in relation to the leveling altered the metered amount of both fertilizers used in all metering mechanisms. The helical with lateral overflow was the metering mechanism that obtained the smallest amount variation of fertilizer distributed in the different longitudinal inclinations, followed by the helical with longitudinal overflow, horizontal toothed rotor, and helical without flow restrictor.

KEYWORDS: powder fertilizer, operational efficiency, granule mixtures, variation in dosage.

INTRODUCTION

Agricultural mechanization can be related to activities of soil tillage, liming, gypsum application, basic fertilization, sowing, spraying of agrochemicals, topdressing fertilization, transport of inputs, water transport, harvesting, and grain transport (Jasper & Paulo, 2013).

The functions of a planter are to open fertilization and sowing grooves, distribute fertilizers and seeds in the grooves, and cover them with a layer of soil (Jasper et al., 2011; Mao et al., 2015; Weirich Neto et al., 2012).

In a survey on the dimensional and ponderal characteristics of precision planters in Brazil, Francetto et al. (2015) indicated that the fertilizer metering mechanisms used were the helical (94.4%), horizontal toothed rotor (2.9%), grooved rotor (2.2%), and horizontal toothed rotor (0.5%).

Selection and optimization of mechanized systems are the main objectives of a rational mechanization. A proper purchase of agricultural machinery is not sufficient if its use is not monitored considering operational and financial aspects (Piacentini et al., 2012).

When assessing a mathematical model and simulating the dynamic behavior of a helical fertilizer metering, Garcia et al. (2012) obtained a reduction in the coefficient of variation (CV) from 30 to 11%. This reduction was achieved due to the application rate compensation and the delay of the action signal. The authors stated that the variation in fertilizer application rate, performed with conventional feed screw applicators, is an intrinsic characteristic of these feeders.

Reynaldo & Gamero (2015) assessed fertilizer-metering mechanisms at longitudinal and transversal leveling angles and concluded that all of them presented errors in the fertilizer dose when submitted to simulations of longitudinal inclinations. Positive inclination angles of $+5^\circ$ and $+15^\circ$ presented the highest dose errors, in addition to variations in the CV values between 5.1 and 30.8%.

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Studying statistical models for selecting helical metering mechanisms with fertilizer discharge devices, Franck et al. (2015) stated that the discharge meter without flow restrictor showed a greater sensitivity regarding the effects of operating inclinations whereas the discharge meter by lateral overflow showed a lower sensitivity.

In order to establish a standard for sowing quality, Weirich Neto et al. (2015) studied sowing activity in 30 farms for five consecutive agricultural crops. The fertilizer distribution models analyzed were the horizontal toothed rotor (5 planters), transversal feed screw (10 planters), and longitudinal feed screw (49 planters) following the sowing. The authors concluded that most of the planters presented fertilizer variation between rows above 40% in the first collection and with the level planter. In addition, the authors proposed to obtain fertilizer collection variations of less than 5% between rows.

Weirich Neto et al. (2013) studied fertilizer positioning at sowing, Lu et al. (2014) worked on a planter project, and Grant et al. (2016) assessed the influence of fertilizer sources on the crop installation. However, these authors did not find in the literature scientific studies examining the horizontal toothed rotor performance of planters as a function of longitudinal inclination to the metering mechanism.

Thus, the aim of this study was to analyze the performance of different fertilizer metering mechanisms of planters (horizontal toothed rotor, helical without flow restrictor, helical with lateral overflow, and helical with longitudinal overflow) as a function of longitudinal inclination (-10 , -5 , 0 , 5 , and 10 degrees).

MATERIAL AND METHODS

The experimental design was a completely randomized design with five treatments and six replications. Treatments consisted of five longitudinal inclinations to the metering mechanism (-10 , -5 , 0 , 5 , and 10 degrees). The mass of fertilizer collected per minute was considered as a replication.

The choice of inclinations was established based on ABNT (1996), standard project 04:015.06–004/1995, which recommends that seed metering tests be performed with a longitudinal inclination of -11° and 11° since there are no standards that establish parameters for building fertilizer metering mechanisms.

Thus, two inclinations close to that established by the standard of seed metering (-10° and 10°) were chosen for this study. We also worked with two intermediate inclinations (-5° and 5°), in addition to an inclination of 0° , position in which the metering mechanisms were leveled longitudinally to the direction of fertilizer distribution.

A test bench from the Laboratory of Agricultural Machines of the ABC Foundation was used for carrying out this experiment. This bench was composed of a fertilizer deposit box and a WEG[®] 1.0 CV single-phase electric motor to drive the meter.

Bench structure allowed an angulation and installation of fertilizer metering mechanisms. Angle was set using a MAGNETIC[®] inclinometer. The metering mechanisms installed on the test bench were a horizontal toothed rotor (Kinapik[®] 313), helical without flow restrictor (Semeato[®] NG), helical with lateral overflow (John Deere[®] ProMeter) and helical with longitudinal overflow (Fertisystem[®] Auto-Lub AP NG) (Figure 1).

The John Deere[®] fertilizer metering has a lateral flow restrictor to the movement of the helicoid whereas the Fertisystem[®] mechanism has a flow restrictor transversal to the movement of the helicoid. In addition, the Semeato[®] fertilizer metering does not have a flow restrictor. For the helical fertilizer metering mechanisms, a 2" step thread (50.8 mm) was used.

Two fertilizers with different characteristics were used: a mixture of granules and powder (Table 1). The analyses followed the standards ISO 5690/1 (1985).

The analyzed variable was the mass flow rate of each metering mechanism. The mass

collected per minute at all longitudinal inclinations with both fertilizers was considered as a replication. This method was adapted from Milan & Gadanha Júnior (1996), who described the procedures for flow rate tests used for assessing fertilizer-metering mechanisms.

In order to promote the equality of the collected mass, the meters were calibrated for a flow of 1.58 kg min^{-1} at zero degrees angulation. The flow rate was extrapolated to a fertilization of 350 kg ha^{-1} , considering a crop with a row spacing of 0.45 m and a fertilizer application speed of 6.0 km hour^{-1} .

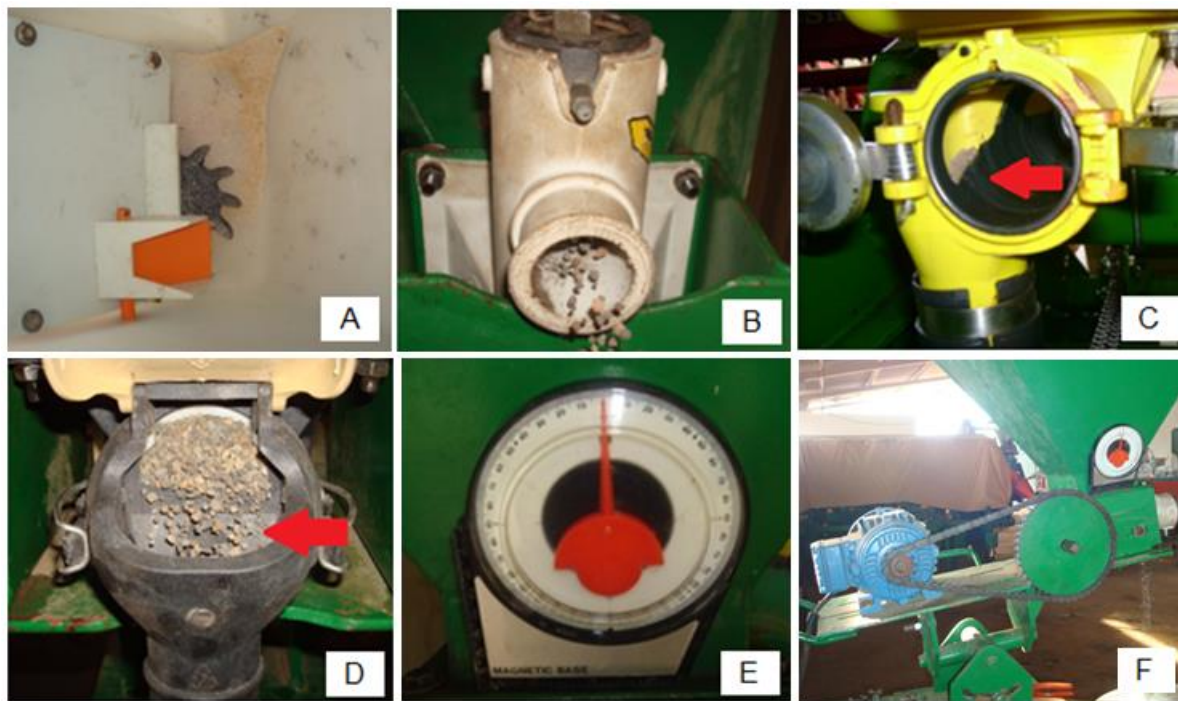


FIGURE 1. Fertilizer metering mechanisms of planters with the systems Kinapik[®] horizontal toothed rotor (A), Semeato[®] helical without flow restrictor (B), John Deere[®] helical with lateral overflow (detail of the flow restrictor) (C), Fertisystem[®] helical with longitudinal overflow (detail of the flow restrictor) (D), inclinometer (E), and test bench (F).

Fertilizer doses were obtained by driving the system with a transmission ratio of 0.27 (motor and driven gear with 12 and 45 traction points). The amount present in the fertilizer deposit box was always half the maximum capacity. Collection times were taken using a digital timer.

The values recorded were submitted to Hartley's test for verifying the homoscedasticity of variances and Kolmogorov-Smirnov test for examining data normality. The F test and polynomial regression were used with a confidence level greater than 95% probability.

TABLE 1. Particle size and physical properties of fertilizers according to ISO 5690/1 (1985) used in the experiment on the performance of fertilizer metering mechanisms of planters as a function of longitudinal inclination, 2012, Ponta Grossa (PR), Brazil.

Particle size (mm)	Fertilizer 1 (%)	Fertilizer 2 (%)
0.125	–	0.17
0.250	–	7.84
0.500	–	32.77
0.710	0.14	40.59
1.000	1.74	12.78
2.000	10.19	5.77
2.800	31.30	–
4.000	51.89	–
> 4.000	4.74	–
Density (g cm ⁻³)	0.99	0.91
Angle of repose (degrees)	37.01	33.32
Humidity (%)	2.43	0.24

RESULTS AND DISCUSSION

The Hartley's and Kolmogorov-Smirnov tests with a confidence level greater than 95% probability were not significant, requiring no data transformation. The F test was significant, indicating the application of the polynomial regression.

The results showed that all longitudinal inclinations to the metering mechanism provided a significant variation, with the linear regression in the fertilizer dosage classified as a mixture of granules and powder.

Fertilizer dosages increased in all the meters when the longitudinal inclination changed from -10° to 10° , but in smaller proportions for meters with overflow when compared to those with horizontal and helical toothed rotor without flow restrictor. This result may affect crop performance due to fertilization importance during sowing (Jasper et al., 2011; Jasper & Paulo, 2013; Mao et al., 2015; Weirich Neto et al., 2012).

For the fertilizer classified as a mixture of granules, the regression showed significant differences in the mass flow rate of fertilizer as a function of variation of the working angle in all fertilizer metering mechanisms (Figure 2). These results are in accordance with those found by Reynaldo & Gamero (2015).

Percentage variations in the average dosage of the fertilizer classified as a mixture of granules in the metering horizontal toothed rotor were -5.9% , -2.9% , 5.9% , and 20.9% in the inclinations -10° , -5° , 5° , and 10° , respectively. The reference value was obtained in the inclination zero degrees.

Based on the amount of fertilizer collected in the inclination zero degrees, the largest percentage variations of the average dosage of mixture of granules were observed in the helical metering without flow restrictor, with values of -29.4% , -7.9% , 7.6% , and 21.9% in the inclinations -10° , -5° , 5° , and 10° , respectively.

From the data obtained in the inclination zero degrees, the helical metering with longitudinal overflow presented percentage variations in the average dosage of granule mixtures of -9.0% , -3.6% , 5.9% , and 9.7% in the inclinations -10° , -5° , 5° , and 10° , respectively.

The helical metering with lateral overflow presented the lowest percentage variations in the average dosage of granule mixtures, with values of -4.4% , -1.0% , 3.7% , and 6.5% in the inclinations -10° , -5° , 5° , and 10° , respectively. The value obtained in the inclination zero was taken as reference.

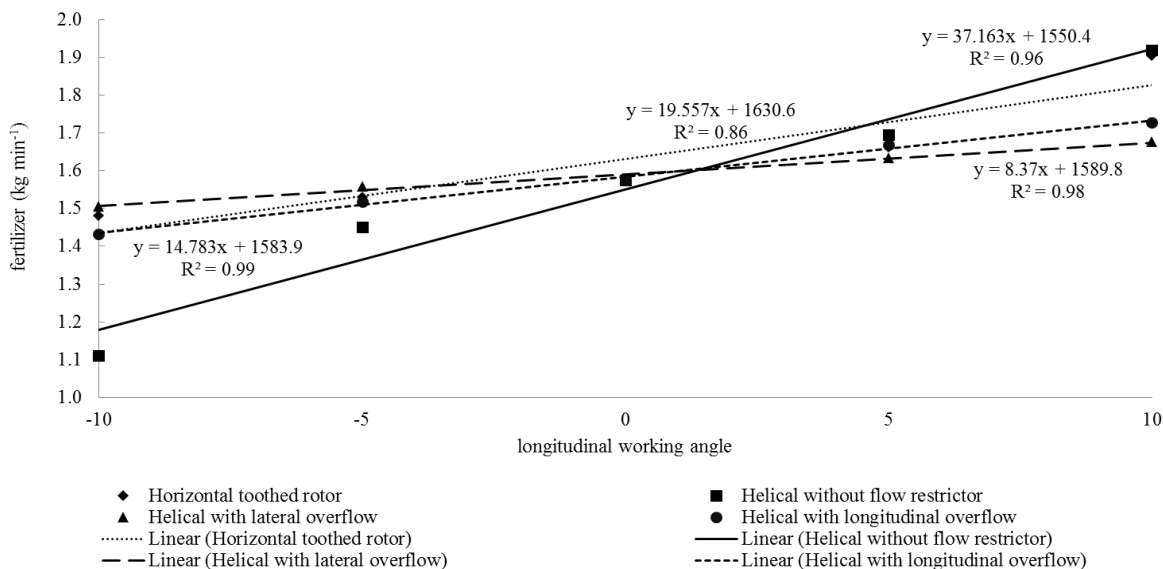


FIGURE 2. Amount of fertilizer classified as a mixture of granules (ISO 5690/1, 1985) distributed by fertilizer metering mechanisms of planters working at different longitudinal angles of inclination on a test bench.

The highest variation was 29.4% in the inclination -10° , obtained with the helical fertilizer metering without flow restrictor. On the other hand, the lowest variation was 1.0% in the inclination of -5° for the helical metering mechanism with lateral overflow. The highest and lowest values were lower than that registered by Weirich Neto et al. (2015) between rows of the level planter.

The percentage of coefficient of variation (CV) of the fertilizer classified as a mixture of granules considering all longitudinal inclinations and metering mechanisms was 10.8%. This value is lower than the lowest CV obtained by Garcia et al. (2012) and higher than those presented by Reynaldo & Gamero (2015).

For the fertilizer classified as powder, the regression also showed significant differences in the mass flow rate of fertilizer as a function of variation of the working angle in all fertilizer metering mechanisms (Figure 3), corroborating with the conclusions of Reynaldo & Gamero (2015).

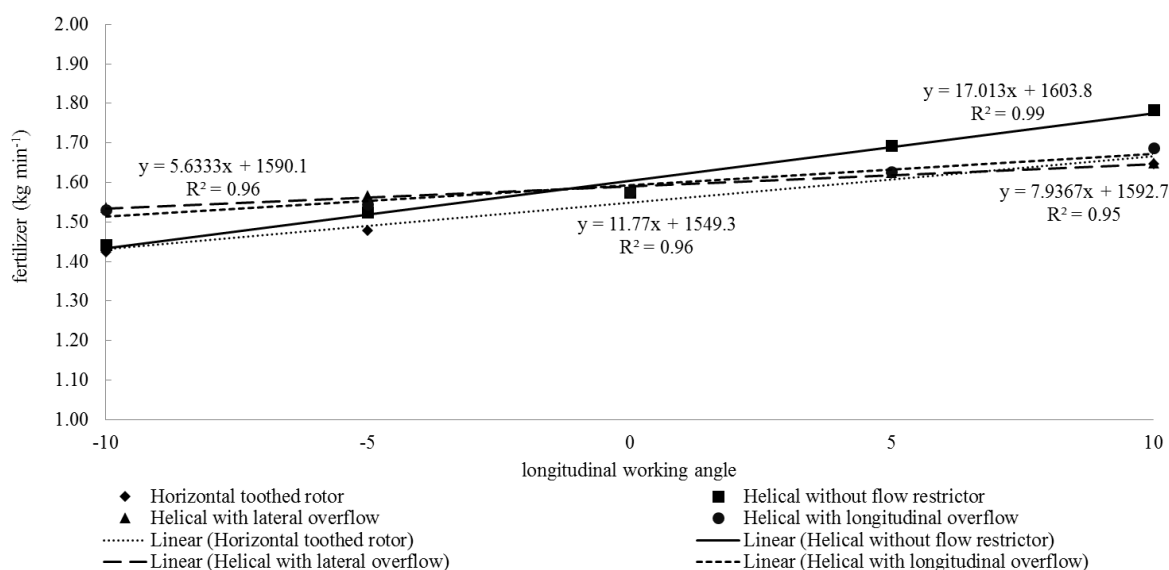


FIGURE 3. Amount of fertilizer classified as a powder (ISO 5690/1, 1985) distributed by fertilizer metering mechanisms of planters working at different longitudinal angles of inclination on a test bench.

Taking as reference the amount of fertilizer obtained in the inclination zero degree, percentage variations in the average dosage of the fertilizer classified as powder in the toothed rotor metering were -9.6% , -6.1% , 3.0% , and 4.5% in the inclinations -10° , -5° , 5° , and 10° , respectively.

In the helical metering without flow restrictor, the percentage variations of the average dosage of powder fertilizer were -8.4% , -3.2% , 7.5% , and 13.3% in the inclinations -10° , -5° , 5° , and 10° , respectively. The value obtained in the inclination zero was taken as reference.

From the inclination zero degrees, the percentage variations of the average dosage of powder fertilizer in the helical metering with longitudinal overflow were -2.9% , -2.0% , 3.2% , and 7.1% in the inclinations -10° , -5° , 5° , and 10° , respectively.

In the helical metering with lateral overflow, the percentage variations of the average dosage of granule mixtures were -2.4% , -0.6% , 3.2% , 4.7% in the inclinations -10° , -5° , 5° , and 10° , respectively. The reference value was obtained in the inclination zero degrees.

The highest variation was 13.3% in the inclination 10° , obtained with the helical fertilizer metering without flow restrictor. On the other hand, the lowest variation was 0.6% , found in the inclination -5° for the helical metering mechanism with lateral overflow. The highest value found is lower than the 40% registered by Weirich Neto et al. (2015) between rows of a level planter. In addition, the lowest value found in our study is lower than the 5.0% between rows observed by those authors.

The coefficient of variation (CV) of the fertilizer classified as a powder was 5.5% for all longitudinal inclinations and metering mechanisms. This value is lower than the CV calculated for granule mixtures obtained by Garcia et al. (2012) and close to those observed by Reynaldo & Gamero (2015).

The lower variation of the fertilizer classified as powder when compared to that classified as granule mixtures may be related to the angle of repose and humidity. The lower angle of repose and humidity of the powder fertilizer characterizes its ease of fluidity, flowing more easily through the fertilizer metering mechanisms of planters when compared to the mixture of granules.

The average amount variation of fertilizer obtained by using the helical metering with lateral overflow as a function of the longitudinal inclination of the metering was lower. The horizontal toothed rotor presented the third lowest variation and the helical metering without flow restrictor presented the highest variation. These results corroborate with the studies presented by Franck et al. (2015).

The problems identified in fertilizer dosing are disquieting considering that 94.4% of the planters available in the Brazilian market are equipped with helical metering mechanisms (Francetto et al., 2015).

Sowing in sloping conditions is common, which indicates that large amounts of fertilizer may be inadequately dosed due to the high terrain slopes at which crops have been cultivated. Because of this, it is important to monitor mechanization considering operational and financial aspects (Piacentini et al., 2012).

CONCLUSIONS

The longitudinal inclination $\pm 10^\circ$ in relation to the leveling altered the metered amount of both fertilizers used in all metering mechanisms.

The helical with lateral overflow was the metering mechanism that obtained the smallest amount variation of fertilizer distributed in the different longitudinal inclinations, followed by the helical with longitudinal overflow, horizontal toothed rotor, and helical without flow restrictor.

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