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Seed distribution by punch seeder in family farming[1]

Distribuição de sementes por uma semeadora puncionadora para agricultura familiar

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ABSTRACT - Family farming seeks to use less-aggressive agricultural practices, however, there is little machinery available that is suitable for the reality of this sector. This has led to the use of technically incorrect practices, which have contributed to the impoverishment, compaction and desertification of agricultural soils. Punch seeders are seen as a promising alternative for carrying out sowing in family farming, as they employ localised seed distribution with less disturbance of the soil and the consequent preservation and conservation of its structure. The aim of this study was to evaluate the quality of seed distribution by a punch seeder used in family farming. The experiment was carried out in a soil classified as a Red-Yellow Argisol. Descriptive statistics were used to evaluate the quality of seed distribution by the punch system. Statistical Process Control was adopted to evaluate quality control in the seed distribution process. The results showed that the performance of the punch seeder was similar to that of the precision pneumatic seeder, with 90.2% acceptable spacing. As demonstrated by the SPC study that showed the process to be compatible with quality standards, the punch seeder is therefore a viable alternative in the sowing process for family farming, since an improvement in sowing quality, with a precision of 88.4% was obtained. The punch system resulted in less soil disturbance when compared to the disc harrow and manual seeder, and proved to be an effective solution for conservation agriculture.

Key words: Quality control. Punch system. Seeding.

RESUMO - A agricultura familiar busca utilizar práticas agrícolas menos agressivas, entretanto existem poucas máquinas adequadas à realidade deste segmento, isso tem levado ao uso de práticas tecnicamente incorretas, que vem contribuindo para o empobrecimento, compactação e desertificação dos solos agrícolas. Diante disso, as semeadoras puncionadoras apresentam-se como uma possibilidade promissora para realizar o processo de semeadura para agricultura familiar, visto que realiza a distribuição de semente de forma pontual, contribuindo para a menor mobilização do solo e consequente preservação e conservação da estrutura do mesmo. O objetivo do trabalho foi avaliar a qualidade de distribuição de sementes por uma semeadora puncionadora para a agricultura familiar. O ensaio foi realizado em um solo classificado como Argissolo Vermelho-amarelo. Foi utilizada a estatística descritiva para avaliar a qualidade da distribuição de sementes pelo sistema puncionador. O Controle Estatístico do Processo foi adotado para avaliar o controle de qualidade do processo de distribuição de sementes. Os resultados demostraram que a semeadora puncionadora apresentou desempenho semelhante à semeadora de precisão pneumática, obtendo 90,2% de espaçamentos aceitáveis, sendo uma alternativa viável para realizar o processo de semeadura para a agricultura familiar, fato comprovado pelo estudo do CEP que indicou a adequação do processo de semeadura aos padrões de qualidade, pois obteve 88,4% de precisão no processo, possibilitando a elevação da qualidade de semeadura. O sistema puncionador proporcionou menor mobilização do solo quando comparado ao sulcador de disco e semeadora manual, mostrando-se como uma solução eficaz para a agricultura conservacionista.

Palavras-chave: Controle de qualidade. Punção. Semeadura.

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INTRODUCTION

Family farming plays a prominent role in agricultural production in the country, and mechanised agriculture is therefore important for the development of the sector. However, of the available equipment, a large part is difficult to operate and maintain, and is unsuitable or inappropriate for the conditions of the family farmer, besides often having poor operating quality (VIANNA; REIS; MACHADO, 2014).

As such, it is necessary to develop equipment aimed at family farming, using technology that can help to increase the quality of work, as well as develop and adapt new machines that enable these farmers to increase their production and productivity (STEFANELLO *et al*., 2014).

For Milagres *et al*. (2015), it is necessary that the design of mechanisms to carry out the seeding process are not always limited to the same conditions, it being important to consider other factors, such as soil type, water content, etc. In this respect, Teixeira *et al*. (2009), point out that there are few machines suitable for the reality of family farming. This has led to the use of technically incorrect practices, and has contributed significantly to the impoverishment of agricultural soils and a reduction in productivity.

It is therefore important to implement new technologies that seek a model of agricultural production where the conservation and management of natural resources prevail. Seeders using a punch system can be an alternative for family farming in Ceará, since they allow less turning of the soil and mulch, which helps to conserve the soil, a requirement that is essential to conservation agriculture (FRABETTI *et al*., 2011).

Punch seeders function by opening holes and then depositing the seeds; these seeders therefore deposit seeds in a localised way, which increases the possibility of raising the yield of crops that are sensitive to uniform plant distribution, besides positioning the seeds in the ground with greater precision (ALBIERO *et al*., 2015).

Research has been developed to design punch seeders for family farming that carry out sowing in equidistant holes, with the aim of providing a distribution system that is reliable, accurate, easy to maintain and operate, and of increasing the profit of the farmer (FRABETTI *et al*., 2011).

In view of the above, the aim of this study was to evaluate the quality of seed distribution by a punch seeder used for family farming.

MATERIAL AND METHODS

The work was carried out in the experimental area of the Department of Agricultural Engineering at the Centre for Agrarian Sciences of the Federal University of Ceará, Pici Campus. The soil in the area is classified as a Red-Yellow Argisol with a sandy-loam texture as per the recommendations of the Empresa Brasileira de Pesquisa Agropecuária (2006).

Table 1 shows values for the physical characteristics of the soil in the experimental area. The mean cone index for the area varied between 0.8 and 1.1 MPa.

During the experiment with the seeder, a distance of 45 metres was marked out for longitudinal distribution of the seeds, with a distance of 5 metres being ignored in the evaluation for the seed dispensing system to stabilise. To evaluate seed distribution, a method of manual digging was used; the holes were opened at random every one metre, and a centimetre rule was used to evaluate the distribution process. The methodology described by Montgomery (1991) was used to determine the minimum number of samples for data normality, employing operating characteristic graphs of bicaudal distribution at 5% significance. After evaluating the preliminary data, a minimum sample size of 30 was determined. The number of seeds was counted for each metre of the sowing row under evaluation, i.e. each seed represented one sample; therefore, for each distribution band, 100 seeds were collected to guarantee data normality. In total, five rows were sown, giving a total of 500 samples. Seed spacing was evaluated as per the recommendations of Kurachi (1989).

A seeder with a punch system was used to perform the test (Figure 1). This system is driven by a camshaft which, when rotated, activates the hole-making system, producing a hole for depositing the seed. The systeem was adjusted to obtain a spacing of 140 mm between seeds, following the recommendations for maize crops (EMPRESA BRASILEIRA DE PESQUISA AGROPECUÁRIA, 2010). A horizontal perforated-disc mechanism was employed to dispense the seeds.

The disturbed area was determined by means of a profilometer containing 50 vertical rods, each 64 cm in length and spaced 1 cm apart. The mean values for the area disturbed by the punch system, the disc harrow and the manual seeder (ratchet) were compared.

The forward speed of the seeder was set to 0.53 m s^{-1}, which is compatible with a commercial rototiller.

During the trial, the hopper of the seeder was consistantly operated at 50% of its volumetric capacity, as recommended by Mialhe (1996).

Table 1 - Physical properties of the experimental área

Soil	Db (kg dm^{-3})	M (g 100g^{-1})	CS (g kg^{-1})	FS (g kg^{-1})	Clay (g kg^{-1})	Silt (g kg^{-1})	OM (g kg^{-1})
Sandy-Loam	1.61	5.54	435	371	118	76	1.69

Db: Bulk density; M: Moisture; CS: Coarse Sand; FS: Fine Sand; OM: Organic Material

Figure 1 - Prototype of the punch seeder with the punch system for depositing the seeds

The wheel slip index of the seeder was measured following the methodology recommended by Mialhe (1996), counting the number of turns made by the wheel of the prototype seeder over a distance of 40 metres. The slip index of the seeder was determined from Equation 1.

$$Sl = \frac{(Pt * N - Cl)}{\Pr * N} \qquad (1)$$

Where:

Sl is the slippage;

Pt is the perimeter travelled by the driven tyre of the machine;

N is the number of runs made along the experimental row;

Cl is the working length of the experimental row.

A completely randomised experimental design was used to test the prototype. Descriptive statistics were used to analyse the following parameters: mean, standard deviation, and the coefficients of variance, symmetry and kurtosis. From the coefficients of symmetry and kurtosis the normality of the studied data was determined as per the recommendations of Montgomery (2004). The MINITAB v 16 statistical software used was in trial mode for thirty days.

Statistical Process Control (SPC) was used to evaluate the seed distribution process for data displaying normality and to verify the stability of the process. The SPC evaluation was based on the C_p and C_{pk} number indices, as per Equation 2.

$$C_p = USL\text{-}LSL/6\sigma \qquad (2)$$

Where:

C_p is the process capability index;

USL is the upper specification limit;

LSL is the lower specification limit;

σ is the standard deviation.

The effective capacity of the process (Cpk) was based on Equations 3, 4 and 5.

$$C_{pk} = \min (C_{Ps1}\ C_{pi}) \qquad (3)$$

$$C_{Ps} = USL\text{-}\mu/3.\sigma \qquad (4)$$

$$C_{Pi} = \mu\text{-}LSL/3.\sigma \qquad (5)$$

Where:

μ is the mean value of the process.

According to Chao (1974), given two random independent variables, each normally distributed, if the variances of these variables are not inter-dependent, it is possible to use the characteristics of the F distribution as a test of hypothesis, employing the F ratio given below. In this test the difference between mean values using the F statistic considers that the various treatment groups comprise one total group, with the variance of the total sample being partitioned into variance within the group and variance between groups; this method is found in the Analysis of Variance (ANOVA).

According to Snedecor and Cochran (1989), ANOVA is a statistical method that develops from the assumption that different populations have different estimates of variance. According to Montgomery (1991), provided that the F ratio is at 5% significance, the most powerful test for comparing mean values is the Least Significant Difference Test (LSD), which investigates all the differences between pairs of mean values. This test consists in calculating the differences between all the existing pairs of mean values using a combination of all treatments (SNEDECOR; COCHRAN, 1989).

RESULTS AND DISCUSSION

To evaluate the number of acceptable spacings, the limits to the frequency class ranges recommended by Kurachi (1989) were used; the author states that the mean value obtained is within the acceptable spacings by classifying values that are less than $0.5.X_{referential}$ as double spacings, values that are within the 140 to $1.5._{referential}$ limits as acceptable, and values greater than $1.5.X_{referential}$ as errors. As the seeder was adjusted to give a spacing of 140 mm between seeds, spacings of 70 to 210 mm were considered normal, double for values less than 70 mm and errors for those over 210 mm.

A speed of 0.53 m s^{-1} was used to carry out the test. This speed allows the prototype to obtain maximum efficiency in the field, in addition to meeting the needs of the family farmer, since any two-wheeled tractor can develop this operating speed. Albiero *et al*. (2012), working with a seeder for family farming at a speed of 0.25 m s^{-1}, concluded that this speed enables a field capacity that is compatible with small Brazilian farms.

Table 2 shows the evaluation of double spacings, acceptable spacings and errors obtained in the field with the seeder prototype.

As can be seen, the punch seeder achieved 4.2% double spacings, 90.2% acceptable spacings and 5.6% errors, thereby obtaining an excellent seed-distribution index. Santos *et al*. (2011), evaluating the spatial analysis of maize-seed distribution by a precision seeder, used the percentage of seeds distributed in the range of acceptable spacings to classify distribution efficiency, considering seeders that distribute from 90 to 100% of the seeds within the range of acceptable spacings to be of optimal performance, those that distribute from 75% to 90% of the seeds of good performance, from 50% to 75% of regular performance and less than 50% of poor performance.

Frabetti *et al*. (2011), evaluating the performance of a punch seeder prototype in the direct sowing of maize, obtained 95.08% regularity in seed distribution, the authors also found that a system for opening holes by means of wheels positioned in a V formation with dispensers coupled to the wheel, is a viable solution for a localised system of sowing maize.

In Table 3 can be seen the descriptive-statistic data of the spacings obtained when evaluating the longitudinal distribution of seeds.

It can be seen that the punch seeder had a mean spacing of 151.19 mm between seeds, a standard deviation of 35.27 mm and a coefficient of variation of 23.28%. The spacing values are evidently greater than those for which the seeder was adjusted, indicating an irregularity during the seed distribution process.

The slip index of the wheels was 9%, which contributed to the above result (mean value of 151.19 mm), as the seeder was adjusted so that a hole was punched every 140 mm to distribute the seeds. Furlani *et al*. (2008) and Corrêa Júnior *et al*. (2010) agree with this assertion, since they point out that the slip index of the wheels is directly related to the effective performance of the seeder.

Another factor that contributed to the seeder not achieving the desired spacing was the large distance between the seed dispenser and the ground; this was due to the position of the camshaft, which was under the dispensing mechanism. It was necessary for the height of the seed dispensing system to be raised so to avoid contact between the two components. Siqueira, Casão Júnior and Araújo (2002) point out that the closer to the ground the seed is ejected from the dispensing mechanism, the more efficient is the longitudinal seed distribution.

Table 2 - Evaluation of double spacings, acceptable spacings and erors of the punch seeder

Evaluation of the spacing between seeds		
Double	Acceptable	Errors
21 (4.2%)	451 (90.2%)	28 (5.6%)

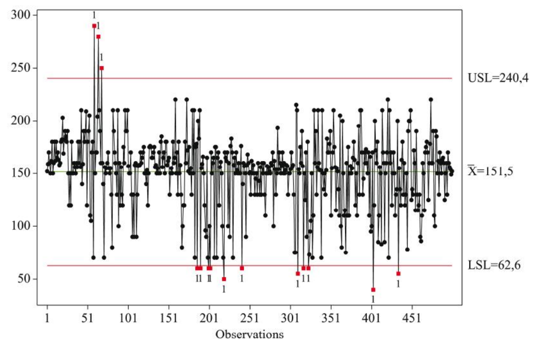
Table 3 - Basic descriptive statistics for the longitudinal distribution of seeds of the punch seeder in a Red-Yellow Argisol

Descriptive statistics of seed distribution								
Observations	M	SD	Var	Min	Max	CV %	Sym	Kur
	---------- mm				----------			
500	151.19	35.27	1244	40	290	23.28	-0.50	1.23

M: Mean; SD: Standard Deviation; Var: Variance; Min: Minimum; Max: Maximum; CV: Coefficient of Variation; Sym: Symmetry; Kur: Kurtosis

It can be seen in Table 3 that the data under evaluation displayed a normal distribution, since, according to Montgomery (2004), if the coefficients of symmetry and kurtosis are within the range of -2 to 2, the data can be considered normal. The author also recommends SPC to evaluate normal processes, since this tool is widely used to evaluate variability and to determine the problem areas of repetitive processes, as is the case of the seeding process. Fernandes, Costa and Souza (2011) agree with this assertion, since the authors state that SPC assists in quality control during the various stages of a process, especially repetitive processes, as it aims to guarantee the stability and continuous improvement of the process. Figure 2 shows the control chart for seed spacing of the punch seeder.

Figure 2 - Control chart for seed spacing of the punch seeder generated by the MINITAB v 16 software



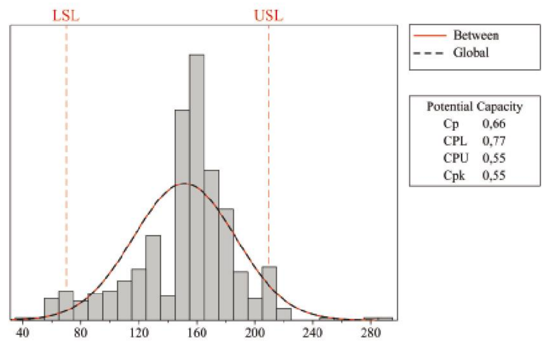
Note that the average spacing was 151.5 mm and that some samples exceeded the specified control limits; as such, the process is considered unstable. However, Albiero *et al*. (2012) and Melo *et al*. (2013) point out that if only 5% of the samples are outside the control limits, the process can be considered stable, the authors defining an error index of around 10% as being optimal, considering that during field operations there is a lot of variability.

Under agricultural conditions these indices are considered good, since agricultural processes are far from having the same control as industrial processes, where all the conditions and factors that can interfere in the process are controlled (MELO *et al*., 2016).

Therefore, it can be said that as the process provided stability, the punch seeder showed satisfactory results, with the samples not exceeding the 5% (25 samples) established by the author.

Figure 3 shows the analysis of the effective seed-distribution capacity of the punch seeder. Effective capacity can be classified from the errors; therefore, for a Cpk <0.33 there is one error in every two samples, when the Cpk ≥ 0.51 there is one error in every eight samples, with a Cpk ≥ 1 one error is considered to occur every 400 samples, and for a Cpk ≥ 1.5, error-occurrence is considered low, with a possible error rate of 1 in every 150,000 evaluated samples (ELSMAR, 2009).

Figure 3 - Analysis of the effective seed-spacing capacity



It can be seen that the value for effective capacity (Cpk) was 0.55, therefore one error was obtained for every 8.62 samples, equal to a process accuracy of 88.4%, with 11.6% of errors.

For the graph in question, when analysing the process using the specifications of Ribeiro and Caten (2011), the analysis of the effective capacity of the process is classified as having failed, since the value of Cpk is less than 1.00, and it can be seen that the distribution process exceeded the specified limits (USL=210 mm and LSL=70 mm), this was due to the influence of specific circumstances, such as the slip index of the seeder.

Quality control is therefore an important tool in agricultural operations, and can help in making decisions that contribute to increases in productivity, since the correction and elimination of waste and errors gives a reduction in costs and a consequent increase in productivity, with innumerable advantages for competitiveness in the field (CHIODEROLI *et al*., 2012).

Table 4 shows basic descriptive statistics for the area disturbed by the manual seeder (ratchet), disc harrow and punch, where it can be seen that the mean value for the area disturbed by the ratchet was 0.0153 m^2, 0.0081 m^2 for the punch and 0.0735 m^2 for the disc harrow.

Table 4 - Descriptive statistics for the area disturbed by the hole-making system for seed deposition, of a manual seeder (ratchet), disc harrow and punch

Descriptive statistics of the hole-making systems for seed deposition in the soil								
	Obs	M	SD	Min	Max	CV %	Sym	Kur
		---- mm ----						
Ratchet	10	0.0153	0.0088	0.0137	0.0165	5.76	-0.60	-0.45
Punch	10	0.0081	0.0008	0.0071	0.0095	10.99	0.35	-1.51
Disc harrow	10	0.0735	0.0076	0.0652	0.0857	10.39	0.64	-0.99

Obs: Observation; M: Mean; SD: Standard Deviation; Min: Minimum; Max: Maximum; CV: Coefficient of Variation; Sym: Symmetry; Kur: Kurtosis

From the above, it can be seen that the largest area of soil was disturbed by the disc harrow. It is important to note that soil disturbance is associated with the working depth of the mechanism, since Modolo *et al*. (2013), evaluating the area disturbed by disc and rod harrows, concluded that the rod harrow caused greater soil disturbance when compared to the disc harrow, and attributed this result to the greater working depth of the mechanism.

It can be seen that the coefficients of symmetry and kurtosis (Table 4) are within the values established by Montgomery (2004), since both are in the range of -2 to 2, with the data considered to show a normal distribution, thereby permitting an analysis of variance of the data.

Table 5 shows the analysis of variance for the area disturbed by the manual seeder (ratchet), disc harrow and punch.

It was found from the F-test, that at 5% significance, there was a significant difference between the mean values of the disturbed areas. As there was a difference between the mean values under evaluation, the mean-value test for the area disturbed by the manual seeder (matraca), disc harrow and punch is shown in Table 6 below.

A statistical difference can be seen for the LSD test at 5% significance; however, the disc harrow showed a greater area of disturbance. It can be seen that the mean value for the manual seeder (ratchet) was superior to that of the punch system, despite also depositing seeds in a localised way. This can be explained by its operating principle: when penetrating the soil, it opens to form the hole and is removed from the ground with the system still open, which contributes to greater soil disturbance, whereas the punch system is removed from the ground with the system closed, thereby disturbing a smaller area compared to the manual seeder.

It should be noted that there was less soil disturbance with the punch system when compared to the disc harrow and the ratchet, showing that, as stated by Frabetti *et al*. (2011), this system results in less soil disturbance; the authors affirm that seeders equipped with a punch system for seed deposition turn the soil less compared to seeders that use rod or disc harrows.

Seeders that have a punch system can be used as an alternative for family farming in Ceará, since the soils found in this region are characterised as shallow, which, due to their morphological, chemical and physical characteristics, helps to make them susceptible to erosive processes.

From the tests carried out to evaluate the performance of the punch seeder, it was found that the punch system has an excellent seed distribution index, as it achieved the same index as a pneumatic seeder, with 90% of the seeds being within the acceptable range. This can be verified by the SPC study that demonstrated the sowing process to be compatible with quality standards, showing that a seeder equipped with a punch system can be an alternative in family farming, since it proved to be an accurate and reliable system. Furthermore, it resulted

Table 5 - Analysis of variance of the area disturbed by the manual seeder (ratchet), harrow and punch

ANOVA					
Source of Variation	DF	SS	MS	F	P
Factor	2	0.0257151	0.0128575	642.92	0.000
Error	27	0.0005400	0.0000200		
Total	29	0.0262550			

DF: Degrees of freedom; SS: Sum of Squares; MS: Mean Squares

Table 6 - Mean-value test for the area disturbed by the ratchet, disc harrow and punch

Mean-value test		
Hole-making system	Number of samples	Mean values for the disturbed área (m^2)
Harrow	10	0.0735 a
Ratchet	10	0.0153 b
Punch	10	0.0081 c

*Mean values followed by the same letter do not differ statistically by the LSD test at a level of 5%

in the least soil turning, since the localised system for depositing the seeds in holes results in less disturbance of the area, which helps to conserve the soil, a requirement which is essential to conservation agriculture; the demand for power to activate the implements was also reduced, helping to reduce fuel consumption.

CONCLUSIONS

1. A seeder with punch system is a viable alternative for sowing in family farming, since it obtained a distribution performance similar to that of a precision pneumatic seeder;
2. It can be concluded from the Statistical Process Control (SPC) analysis, that the process of the punch seeder is stable and that is has a satisfactory Process Capacity (CPk), with 88% sowing accuracy;
3. The punch mechanism resulted in less soil disturbance, proving to be an effective solution when considering the principles of conservation agriculture.

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REFERENCES

ALBIERO, D. *et al*. Avaliação da distribuição de sementes por uma semeadora de anel interno rotativo utilizando média móvel exponencial. **Revista Ciência Agronômica**, v. 43, n. 1, p. 86-95, 2012.

ALBIERO, D. *et al*. Tecnologias agroecológicas para o semiárido. *In:* MELO, R. P. *et al*. **Semeadoras agroecológicas**. Fortaleza, 2015. cap. 8, p. 122-135. Edição do autor.

CHAO, L. L. **Statistics**: methods and analyses. 2nd. ed. New York: McGraw-Hill, 1974. 359 p.

CHIODEROLI, C. A. *et al*. Perdas de grãos e distribuição de palha na colheita mecanizada de soja. **Bragantia**, v. 71, n. 1, p. 112-121, 2012.

CORRÊA JÚNIOR, D. *et al*. Influência da velocidade de deslocamento no desempenho de uma semeadora-adubadora de tração animal. **Global Science and Technology**, v. 3, n. 3, p. 50- 58, 2010.

EMPRESA BRASILEIRA DE PESQUISA AGROPECUÁRIA. Centro Nacional de Pesquisa de Solos. **Sistema brasileiro de classificação de solos**. 2. ed. Rio de Janeiro, 2006. 306 p.

EMBRAPA MILHO E SORGO. **Plantio**. 6. ed. 2010. (Embrapa Milho e Sorgo. Sistema de produção,1). Disponível em: < http://www.cnpms.embrapa.br/publicacoes/milho_1_ed/plantespaca.htm>. Acesso em: 24 set. 2016.

ELSMAR. FMEA. 2009. Disponível em: <http://wWww.elsmar.com>. Acesso em: 24 ago. 2016.

FERNANDES, A. E. S.; COSTA, C. E. S.; SOUZA, E. S. O. O uso de controle estatístico de processo na gestão de qualidade. Estudo de caso: Grupo Coringa - AL. **Inovação, Gestão e Produção**, v. 3, n. 6, p. 1-10, 2011.

FRABETTI, D. R. *et al*. Desenvolvimento e avaliação do desempenho de uma semeadora puncionadora para plantio direto de milho. **Revista Brasileira de Engenharia Agrícola e Ambiental**, v. 15, n. 2, p. 199-204, 2011.

FURLANI, C. E. A. *et al*. Semeadora-adubadora: exigências em função do preparo do solo, da pressão de inflação do pneu e da velocidade. **Revista Brasileira Ciências do Solo**, v. 32, n. 1, p. 345-352, 2008.

KURACHI, S. A. H. *et. al*. Avaliação tecnológica de semeadoras e/ou adubadoras: tratamento de dados de ensaios e regularidade de distribuição longitudinal de sementes. **Bragantia**, v. 48, n. 2, p. 249-262, 1989.

MELO, R. P. *et al*. Análise do controle de qualidade de um terraceador trabalhando em um Argissolo Vermelho amarelo. **Brazilian Journal of Biosystems Engineering**, v. 10, n. 2, p. 210-216, 2016.

MELO, R. P. *et al*. Qualidade na distribuição de sementes de milho em semeadoras em um solo cearense. **Revista Ciência Agronômica**, v. 44, n. 1, p. 94-101, 2013.

MIALHE, L. G. **Máquinas agrícolas**: ensaios e certificação. Piracicaba: FEALQ, 1996. 722 p.

MILAGRES, R. S. *et al*. Desempenho de um conjunto trator-semeadora-adubadora em função do mecanismo sulcador e velocidade de deslocamento. **Engenharia na agricultura**, v. 23, n. 2, p. 143-153, 2015.

MODOLO, A. J. *et al*. Semeadura de milho com dois mecanismos sulcadores sob diferentes intensidades de pastejo. **Revista Engenharia Agrícola**, v. 33, n. 6, p. 1200-1209, 2013.

MONTGOMERY, D. C. **Design and analysis of experiments**. 3rd. ed. New York: John Wiley and Sons, 1991. 651 p.

MONTGOMERY, D. C. **Introdução ao controle estatístico da qualidade**. 4. ed. Rio de Janeiro: LTC, 2004. 532 p.

RIBEIRO, J. L. D.; CATEN, S. T. **Controle estatístico do processo**: cartas de controle para variáveis, cartas de controle para atributos, função de perda quadrática, análise de sistemas de medição. Porto Alegre: FEENG: UFRGS, 2011. 172 p.

SANTOS, A. J. M. *et al*. Análise espacial da distribuição longitudinal de sementes de milho em uma semeadora-adubadora de precisão. **Bioscicence Journal**, v. 27, n. 1, p. 16-23, 2011.

SIQUEIRA, R.; CASÃO JÚNIOR, R.; ARAÚJO, A. G. Plantadoras, plantio direto: ângulo ideal. **Cultivar máquinas**, v. 13, p. 30-32, 2002.

SNEDECOR, G. W.; COCHRAN, W. G. **Statistical methods**. 8. ed. Ames: Iowa University Press, 1989. 489 p.

STEFANELLO, G. *et al*. Estrutura funcional de uma semeadora de tração humana. **Ciência Rural**, v. 44, n. 9, p. 1583-1588, 2014.

TEIXEIRA, S. S. *et al*. Caracterização da produção agroecológica do sul do Rio Grande do Sul e sua relação com a mecanização agrícola. **Engenharia Agrícola**, v. 29, n. 1, p. 162-171, 2009.

VIANNA, L. R.; REIS, A. V. dos; MACHADO, A. L. T. Desenvolvimento de dosador de sementes com dupla saída para disco horizontal. **Revista Brasileira de Engenharia Agrícola e Ambiental**, v. 18, n. 10, p. 1086-1091, 2014.