



## QUALITY OF LONGITUDINAL SEED DISTRIBUTION IN MAIZE CULTIVATION IN THE AMAZON REGION

Talles Oliveira Carvalho<sup>1</sup> , Henrique da Silva Barata<sup>1</sup> , Job Teixeira de Oliveira<sup>2\*</sup> , Fernando França da Cunha<sup>3</sup> , Cassiano Garcia Roque<sup>2</sup> , José Nilton da Silva<sup>1</sup> , Priscilla Andrade Silva<sup>4</sup>  & Vicente Filho Alves Silva<sup>1</sup> 

1 - Federal Rural University of the Amazon, Parauapebas, Pará, Brazil

2 - Federal University of Mato Grosso do Sul, Campus CPCS, Chapadão do Sul, Mato Grosso do Sul, Brazil

3 - Federal University of Viçosa, Viçosa, Minas Gerais, Brazil

4 - Federal Rural University of the Amazon, Belém, Pará, Brazil

### Keywords:

Assessment  
Cultivar  
Precision farming  
Zea mays

### ABSTRACT

Several factors interfere in the efficiency of the seeding process in planting system, with the quality of longitudinal seed distribution being particularly critical. This study aimed to identify the most productive maize hybrid under the prevailing soil conditions and to evaluate the quality of seed longitudinal distribution during cultivation. The experimental design consisted of strip plots with seven treatments and five repetitions. The treatments comprised the following hybrid maize cultivars: EXP T14M774265, Balu 761, EXP T14M6520, EXP T14M713265, Balu 383 VIP 3, EXP T14M7641 and EXP 7132MT14. The variable evaluated included maize productivity, soil pH, soil mechanical resistance to penetration (RP) and the percentage of normal, double and missing crop spacing. Data were subjected to analysis of variance (ANOVA), and means were compared using Tukey's test when the F-test was significant at the 5% probability level. No significant differences were observed in soil pH (measured in both H<sub>2</sub>O and KCl), and soil compaction levels remained within acceptable limits, indicating favorable conditions for plants development. However, the seed longitudinal distribution exhibited high variability, attributed to inadequate planter calibration. Among the hybrids tested, EXP T14M6520 (C3) exhibited the highest average productivity, reaching 8.43 t ha<sup>-1</sup>.

### Palavras-chave:

Avaliação  
Cultivar  
Agricultura de precisão  
Zea mays

### QUALIDADE DA DISTRIBUIÇÃO LONGITUDINAL DA CULTURA DO MILHO NA REGIÃO AMAZÔNICA

#### RESUMO

Vários fatores interferem na excelência do processo de semeadura em sistema de plantio, destacando-se entre eles a qualidade da distribuição longitudinal. Objetivou-se identificar a cultivar de milho mais produtiva nas condições de solo em que as plantas cresceram, e determinar a qualidade da distribuição longitudinal do cultivo. O delineamento utilizado no trabalho foi em faixas com 7 tratamentos e 5 repetições. Os tratamentos foram as cultivares híbridas de milho: EXP T14M774265, Balu 761, EXP T14M6520, EXP T14M713265, Balu 383 VIP 3, EXP T14M7641 e EXP 7132MT14. Foram avaliados: produtividade, pH do solo, resistência mecânica do solo à penetração (RP) e a porcentagem de espaçamento normal, duplo e defeituoso da cultura. Os dados foram submetidos à análise de variância e, quando o valor do teste F foi significativo a pelo menos 5% de probabilidade, foi utilizado o teste de Tukey para comparação das médias. Não houve diferença nas médias de pH em H<sub>2</sub>O e em pH em KCl. Não foi identificadas condições de compactação no solo acima dos limites aceitáveis. As plantas desenvolveram-se em boas condições de solo. A distribuição longitudinal das sementes neste estudo apresentou uma grande variação percentual. Isso ocorreu devido ao ajuste inadequado da máquina. O híbrido EXP T14M6520 (C3) foi o que mais se destacou no cultivo, apresentando média 8,43 t ha<sup>-1</sup> de produtividade.

## INTRODUCTION

During the 2022–2023 period, the United States produced approximately 348 million metric tons of maize (Singh *et al.*, 2024). Of this total, about 166 million tons were processed through wet milling for various applications, including 130 million tons for fuel ethanol production, as well as for food and industrial uses (USDA ERS, 2023, USDA NASS, 2023). Globally, the United States ranks first in maize production, consumption, and exports. In the 2022–2023 harvest, it accounted for 30% of global maize production, leading the top five producers: China, Brazil, the European Union and India (which had production comparable to Argentina) (USDA FAS, 2023).

Maize production in Brazil for the 2024/2025 harvest was estimated at 126.9 million tons, considering all three cropping harvests. The first crop cultivation was expected to produce 24.7 million tons, followed by 99.8 million tons from the second harvest, and 2.4 million tons from the third harvest (Conab, 2025).

Maize is particularly relevant crop for research, as it provides a basis for future agricultural advances. As a major commodity, it has expanded its presence in the national territory, following a similar trajectory to other traditional crops such as beans, rice and sugarcane. Historically, these crops were cultivated with lower technological input, often relying on non-arable lands and the natural fertility of soils (Alves *et al.* 2019, Pinheiro *et al.* 2021).

It is well established that the State of Pará contains extensive areas of soil with high agricultural potential which, when properly managed, corrected and fertilized, and combined with the use of suitable cultivars, can achieve productivity levels comparable to those of major agricultural regions (Silva Pinheiro *et al.*, 2024; Souza *et al.* 2002).

According to Nestlehner (2018), several factors influence the effectiveness of the sowing process in no-tillage system, with operating speed being one of the most critical. Increased sowing speed

negatively affects seed placement, leading to reduced accuracy in longitudinal distribution and sowing depth, as speed is inversely proportional to sowing quality.

The state of Pará has expanded its maize cultivation area in recent years (Brito *et al.*, 2024). Therefore, it is essential to identify the cultivars being planted and to understand the sowing systems used. Based on this context, the hypothesis of this study is that inadequate longitudinal distribution of seeds in the soil negatively affects maize productivity. Considering the productive potential of the Parauapebas-PA region, the objective of this study was to identify the maize hybrid with the highest productivity under the region's soil conditions and to assess the quality of the longitudinal seed distribution during crop establishment.

## MATERIAL AND METHODS

This study was conducted at the Technological Center for Family Agriculture, in the municipality of Parauapebas-PA, located at 06°12'45" S and 49°51'14" W, at an altitude of 197 meters. According to Köppen-Geiger classification, the region has a hot and humid tropical climate (Aw), characterized by high annual precipitation. The dry season occurs from May to November, while the rainy season, known locally as the "rainy winter", precipitation can reach up to 2800 mm. During this period, relative humidity exceeds 90%, and the average annual temperature is approximately 29 °C. The local soil was classified as Yellow-Red Latosol, according to Embrapa (2018).

During the experiment in 2019, April was the rainiest month within the experimental period, with a recorded precipitation of 250 mm. In comparison, May had 98 mm of precipitation, while June was the driest month, with only 38 mm of precipitation. Soil granulometric and chemical analyses (Table 1) were conducted at a depth of 0.0 - 0.2 m, shortly after sowing. Composite soil samples, representative of the entire experimental area, were collected from this depth range.

**Table 1.** Particle size and chemical composition of the experimental area at a depth of 0.0 to 0.2 m, in Parauapebas-PA in 2019

| Depth   | Clay               | Silt    | Sand    | Ca                   | Mg    | H+Al  | K     | OM               | pH    |
|---------|--------------------|---------|---------|----------------------|-------|-------|-------|------------------|-------|
|         | g kg <sup>-1</sup> |         |         | mol kg <sup>-1</sup> |       |       | %     | H <sub>2</sub> O |       |
| 0-0.2 m | 512.490            | 168.240 | 319.270 | 0.050                | 0.004 | 0.021 | 0.004 | 1.330            | 6.090 |

Ca=Calcium; Mg=Magnesium; H+Al= Hydrogen + Aluminum; OM= Organic matter

This study utilized a strip-plot experimental design with seven treatments and five repetitions. The treatments consisted of hybrid maize cultivars: EXP. T14M774265, Balu 761, EXP T14M6520, EXP T14M713265, Balu 383 VIP 3, EXP T14M7641, EXP 7132MT14. The allocation of cultivars to experimental units was randomized. For clarity, the hybrids were designated C1, C2, C3, C4, C5, C6 and C7 respectively.

The experimental area was prepared using conventional tillage, which involved disc plowing to a depth of 30 cm, followed by harrowing. Fertilization was carried out with 110 kg ha<sup>-1</sup> of nitrogen, 150 kg ha<sup>-1</sup> of phosphorus (applied in three stages: one-third at planting and two-thirds as topdressing), 90 kg ha<sup>-1</sup> of potassium, and 50 kg ha<sup>-1</sup> of FTE BR 12, a blended mineral fertilizer containing essential micronutrients.

Planting was performed on April 3, 2019, using the Jumil-2040 G2 mechanical seeder-fertilizer, equipped with a double offset disc system for fertilizer distribution. The equipment operated with five rows spaced 0.70 meters apart and was pulled by a 4x2 tractor in fourth gear with reduced transmission at 1700 RPM, achieving a working speed of 4 km h<sup>-1</sup>. A uniform planting density of approximately 60,000 plants ha<sup>-1</sup> was used for all treatments.

Data collections were performed on April 27, 2019, with the objective of evaluating the initial crop performance and assessing the longitudinal distribution of the plants. Soil pH in H<sub>2</sub>O and KCl was determined following the methodology recommended by Embrapa (2017). The analyses were conducted in the laboratory of the Federal Rural University of the Amazon using soil samples collected with Dutch auger to a depth of 0.20 meters.

Soil resistance to penetration (RP) was measured using a LOG FALKER electronic penetrometer (Falker, Brazil). Measurements were taken at five

randomly selected points within a representative area of each cultivar treatment. In this study, soil compaction was considered acceptable when RP values were below 2.6 MPa, following the threshold proposed by Canarache (1990).

Longitudinal distribution was assessed based on the percentage of normal, double and missing spacings between seeds and plants. Initially, seed placement along the planting row was inspected, and relevant information was recorded. Germination was subsequently verified, confirming that 100% of the distributed seeds had germinated. Plant-to-plant distances were then measured along a 3-meter segment of the row (Figure 1), with five replicates per treatment. Measurements were consistently taken from the same planting rows at 15-day intervals.



Source: The author, 2024

**Figure 1.** Evaluation of longitudinal distribution of plants

The data were subjected to analysis of variance (ANOVA), and when the F-test was significant at the 5% probability level, mean comparisons were performed using the Tukey test ( $p \leq 0.05$ ).

Statistical analyses were conducted using the SISVAR software (Ferreira, 2019).

## RESULTS AND DISCUSSION

No significant differences were observed in the mean pH values measured in H<sub>2</sub>O (indicating actual soil acidity) or in KCl (reflecting potential acidity) (Table 2). These results suggest that all plants developed under comparable soil acidity conditions.

Although variations in soil pH values were observed among treatments, no significant differences were detected for either pH in H<sub>2</sub>O or for pH in KCl. The pH in H<sub>2</sub>O ranged from 6.2 to 6.8, while pH in KCl ranged from 5.4 to 6.0. All cultivars were grown under conditions considered ideal for soil acidity, with the exception for cultivar 7, which exhibited a potential acidity (pH in KCl) of 5.4—slightly below the recommended range of 5.5 to 6.5 for optimal maize development in the Amazon region (Silva, 2003). The limited variation in pH is likely due to the relatively small experimental area (two hectares), as pH variation tends to be more pronounced over larger spatial scales.

Regarding soil penetration resistance (RP), significant differences were observed among treatments (Table 2), with the highest value observed at 1.41 MPa in the soil where cultivar 5 was grown. However, none of the mean RP values exceeded 2.6 MPa, the threshold beyond which soil compaction may restrict crop development (Oliveira *et al.* 2020). This findings indicate

that none of the cultivars experienced limiting compaction conditions during cultivation. Although RP values varied depending on the treatment, they remained below the critical resistance limit (Vigolo *et al.*, 2024). Excessive soil compaction can lead to significant reductions in crop performance, affecting both root development and the aerial part (Resende Neto *et al.*, 2024).

According to the standard protocol proposed by Correa *et al.* (2020), acceptable plant spacing in this study was defined as ranging from 0.5 to 1.5 times the average spacing within each evaluated row. Spacings greater than 1.5 times the average were classified as missing (faulty) spacings, while those less than 0.5 times the average were considered double spacings. The mean percentages of normal, double and missing spacings for each cultivar are presented in Table 3. The results indicated substantial variation in longitudinal plant distribution among cultivars.

Cultivar 1 exhibited the highest percentage of normal spacing among all treatments, with 88% of spacings classified as adequate. In contrast, cultivar 2 showed the lowest percentage of normal spacing, with only 52% of spacings falling within the acceptable range. Irregularities in longitudinal plant distribution can negatively impact crop performance, as non-uniform spacing may lead to inefficient use of available resources such as water, nutrients, and light.

Correia *et al.* (2020) concluded that higher tire inflation pressure can influence planter

**Table 2.** Mean values and standard deviations for soil pH in H<sub>2</sub>O, pH in KCl and resistance to penetration (RP)

| Cultivar      | pH-H <sub>2</sub> O  | pH-KCl               | RP (MPa)        |
|---------------|----------------------|----------------------|-----------------|
| C1            | 6.2 ± 0.14 a         | 6.0 ± 0.16 a         | 1.07 ± 0.11 ab  |
| C2            | 6.2 ± 0.16 a         | 6.0 ± 0.11 a         | 1.05 ± 0.11 ab  |
| C3            | 6.4 ± 0.41 a         | 5.8 ± 0.57 a         | 1.15 ± 0.10 abc |
| C4            | 6.2 ± 0.22 a         | 5.8 ± 0.29 a         | 1.28 ± 0.19 abc |
| C5            | 6.4 ± 0.15 a         | 6.0 ± 0.11 a         | 1.41 ± 0.21 c   |
| C6            | 6.8 ± 0.14 a         | 6.0 ± 0.14 a         | 1.33 ± 0.25 bc  |
| C7            | 6.2 ± 0.17 a         | 5.4 ± 1.32 a         | 0.96 ± 0.13 a   |
| <b>F Test</b> | 0.4185 <sup>ns</sup> | 0.5524 <sup>ns</sup> | 0.0010*         |
| <b>CV (%)</b> | 7.6                  | 9.3                  | 14.10           |
| <b>DMS</b>    | 0.98                 | 1.10                 | 0.33            |

Means followed by the same letter in the column do not differ significantly by Tukey's test for a 5% probability level; RP = Mechanical Soil Resistance to Penetration. DMS = Minimum significant difference; ns = not significant; \* = significant at the 5% probability level; CV - coefficient of variation. The values represent the mean ± standard deviation. The cultivars were designated as follows: C1-EXP. T14M774265, C2-Balu 761, C3-EXP T14M6520, C4-EXP T14M713265, C5-Balu 383 VIP 3, C6-EXP T14M7641, and C7-EXP 7132MT14

performance. Specifically, a pressure of 241 kPa (35 psi) was associated with a lower rate of missed and double spacings, a reduced coefficient of variation in seed spacing, and greater precision in the longitudinal distribution of deposited seeds. Thus, although variability in longitudinal distribution was observed for most treatments, it is unlikely that tire pressure alone was responsible for this outcome. It is more plausible that a combination of factors contributed to the observed variation, including proper calibration of the seeder, adequate lubrication of mechanical components, correct adjustment of clearances, and overall machine condition. Additionally, the advanced age of the implement and the lack of regular maintenance, as recommended by the manufacturer, may have further compromised sowing precision. According to Vasconcellos (2019), the performance of seeders is directly influenced by the operating

speed, which can affect both sowing quality and overall machine efficiency. In general, increased sowing speeds are associated with reduced sowing quality, including the lower plant stand establishment, increased incidence of missed plants, irregular spacing, and a higher rate of mechanical seed damage. Although sowing speed was standardized in the present study, it is possible that inadequate equipment ballast contributed to slippage rates exceeding recommended limits. This, in turn, may have influenced the variation observed in the longitudinal distribution of seeds. The productivity values of the different maize cultivars evaluated in the study is presented in Table 4.

With the exception of the second hybrid, all treatments exhibited higher productivity than the national average of 5.624 tons ha<sup>-1</sup> (Conab 2024), confirming the favorable productivity

**Table 3.** Mean percentages of normal, double and missing spacings in each treatment

| Cultivar | Normal | Double | Missing |
|----------|--------|--------|---------|
|          |        | (%)    |         |
| C1       | 88.00  | 0.00   | 12.00   |
| C2       | 52.84  | 12.72  | 34.44   |
| C3       | 81.52  | 7.42   | 11.06   |
| C4       | 69.24  | 8.04   | 22.70   |
| C5       | 84.10  | 5.16   | 10.74   |
| C6       | 71.70  | 7.60   | 20.68   |
| C7       | 72.82  | 3.50   | 23.68   |

Cultivar were designed as follows: C1-EXP T14M774265, C2-Balu 761, C3-EXP T14M6520, C4-EXP T14M713265, C5-Balu 383 VIP 3, C6-EXP T14M7641, and C7-EXP 7132MT14

**Table 4.** Mean productivity values of maize cultivars

| Cultivar      | Productivity          |
|---------------|-----------------------|
|               | (t ha <sup>-1</sup> ) |
| C1            | 7.97 ± 0.53 bc        |
| C2            | 5.38 ± 0.49 a         |
| C3            | 8.43 ± 1.40 c         |
| C4            | 7.23 ± 0.57 bc        |
| C5            | 6.26 ± 0.97 ab        |
| C6            | 7.66 ± 0.85 bc        |
| C7            | 7.62 ± 0.78 bc        |
| <b>F test</b> | 0.0001*               |
| <b>CV (%)</b> | 11.79                 |
| <b>DMS</b>    | 1.71                  |

Means followed by the same letter in the column do not differ by Tukey's test at the 5% probability level; DMS = Minimum significant difference; ns = not significant; \* = significant at the 5% probability level; CV - coefficient of variation. Values are expressed as mean ± standard deviation.

performance of the cultivars. Kopper *et al.* (2017) reported productivity values of 7.5 tons ha<sup>-1</sup>, which surpassed the performance of only two cultivars in the present study (C2 and C5). In contrast, Oliveira *et al.* (2021) reported productivity exceeding 11 tons ha<sup>-1</sup> in a study evaluating different irrigation regimes.

The productivity results were favorable for all treatments. The highest average productivity was observed for cultivar C3, with 8.43 t ha<sup>-1</sup>, which did not differ statistically from cultivars C1 (7.97 t ha<sup>-1</sup>), C4 (7.23 t ha<sup>-1</sup>), C6 (7.66 t ha<sup>-1</sup>), and C7 (7.62 t ha<sup>-1</sup>). The lowest productivity were recorded for cultivars C2 and C5, with 5.38 and 6.26 t ha<sup>-1</sup>, respectively. According to Conab (2025), the average maize productivity in Brazil during the 2024/2025 harvest was 5.93 t ha<sup>-1</sup>. Therefore, most of cultivars evaluated in this study exhibited higher productivity than the national average, with the exception of cultivar C2, which yielded 5.38 t ha<sup>-1</sup>. These results suggest that, despite irregularities in longitudinal seed distribution, overall productivity remained satisfactory when compared to national benchmarks.

It is important to highlight the growing global concern regarding maize productivity. Human activities have significantly contributed to global climate alterations and over the past two decades, the intensification of an extreme phenomenon—climate change—has exacerbated climate variability. This variability has produced widespread impacts across all geographic scales, posing significant challenges to agricultural systems globally, particularly in maize production (Cruz-González *et al.*, 2024).

Addressing climate requires strategic actions, including the development of new maize varieties with extended growing seasons, the adoption of more efficient irrigation systems, and improvements in irrigation management to enhance water and food security while minimizing the risk of conflicts over water resources (Gonçalves *et al.*, 2024). These results contribute to the ongoing discourse on effective strategies for mitigating climate change impacts and promote sustainable resource security at both national global levels.

## CONCLUSION

- The plants developed under favorable soil conditions. However, considerable variation

was observed in the longitudinal distribution of seeds, primarily due to inadequate machine calibration. Among the evaluated cultivars, the hybrid EXP T14M6520 (C3) exhibited the highest performance, with a mean productivity of 8.43 t ha<sup>-1</sup>.

## AUTHORSHIP CONTRIBUTION STATEMENT

**CARVALHO, T. O.:** Conceptualization, Data curation, Methodology, Supervision, Writing – review & editing; **BARATA, H. S.:** Formal Analysis, Funding, Writing – review & editing; **OLIVEIRA, J. T.:** Data curation, Project, Writing – review & editing; **CUNHA, F. F.:** Formal Analysis, Methodology, Software, Supervision, Writing – review & editing; **ROQUE, C. G.:** Funding, Methodology, Writing – review & editing; **SILVA, J. N.:** Formal Analysis, Funding, Writing – review & editing; **SILVA, P. A.:** Data curation, Supervision, Visualization, Writing – review & editing; **SILVA, V. F. A.:** Conceptualization, Funding, Writing – review & editing.

## DECLARATION OF INTEREST

The authors declare that they have no financial or personal interests that could influence the work reported in this article.

## ACKNOWLEDGMENTS

The authors would like to thank the Fundação de Apoio ao Desenvolvimento do Ensino, Ciência e Tecnologia do Estado de Mato Grosso do Sul (FUNDECT), Universidade Federal de Mato Grosso do Sul (UFMS) and Universidade Federal Rural da Amazônia (UFRA).

## REFERENCES

Alves, E., Souza, G.S., & Garagorry, F.L. A evolução da produtividade do milho. *Revista de Economia e Sociologia Rural*, v. 37: 77-96. 2019 <https://www.revistasober.org/journal/resr/article/5d962dc40e8825b90d2bac33>.

- Brito, A.E.A., Silva, P.A., Oliveira, J.T., Roque, C.G., Castro, T.R., & de Oliveira Neto, C.F. Nitric Oxide as an Attenuator of Copper Toxicity in the concentration of Nutrients in maize Seedlings. *Revista Engenharia na Agricultura-REVENG*, v. 32(Continua), 16-26. 2024. DOI: 10.13083/reveng.v32i1.16812v.32, p.16-26, 2024
- Conab - Companhia Nacional de Abastecimento. Acompanhamento da safra brasileira de grãos 2024/2025. v. 12, n. 8 oitavo levantamento, maio 2025. 119 p. 2025. <https://www.gov.br/conab/pt-br/atuacao/informacoes-agropecuarias/safras/safra-de-graos/boletim-da-safra-de-graos/8o-levantamento-safra-2024-25/boletim-da-safra-de-graos>.
- Cruz-González, A., Arteaga-Ramírez, R., Sánchez-Cohen, I., Soria-Ruiz, J., & Monterroso-Rivas, A. I. Impacts of climate change on corn production in Mexico. *Revista mexicana de ciencias agrícolas*, v. 15 n.1. 2024. <https://doi.org/10.29312/remexca.v15i1.3327>
- Embrapa - Empresa Brasileira de Pesquisa Agropecuária. Manual de métodos de análise de solo. 3ª edição revista e ampliada. Embrapa. Brasília, DF. 575p. 2017 ISBN 978-85-7035-771-7.
- Embrapa - Empresa Brasileira de Pesquisa Agropecuária. Sistema brasileiro de classificação de solos. Embrapa. 5ª. edição revista e ampliada. Brasília, DF: 2018 ISBN 978-85-7035-817-2.
- Ferreira, D.F. Sisvar: A computer analysis system to fixed effects split plot type designs. *Revista Brasileira de Biometria*, v. 37:529-535. 2019. DOI: <https://doi.org/10.28951/rbb.v37i4.450>.
- Gonçalves, I.Z., Fattori, I.M., Neale, C.M., Santos, C.A., Ruane, A., Phillips, M.M., & Marin, F.R. How can Future Climate Change Affect the Corn Production System in Nebraska, USA?. *International Journal of Plant Production*, p.1-15. 2024. DOI: <https://doi.org/10.1007/s42106-024-00310-6>
- Kopper, C.V., Meert, L., Krenski, A., BORGUI, W., Oliveira Neto, A.M., & Figueiredo, A.S.T. Produtividade de Milho Segunda Safra em Função de Diferentes Velocidades de Semeadura e Densidade de Plantas. *Pesquisa Agropecuária Pernambucana*. Recife. v. 22: 1-6. 2017. <http://dx.doi.org/10.12661/pap.2017.003>.
- Nestlehner, F.M. Distribuição de sementes de milho em função da velocidade de semeadura; Faculdade da Amazônia de Vilhena; v. 1, 26p. 2018. <http://repositorio.fama-ro.com.br/handle/123456789/91>.
- Oliveira, J.T., Oliveira, R.A., Valente, D.S.M., Ribeiro, I.S., & Teodoro, P.E. Spatial Relationships of Soil Physical Attributes with Yield and Lateral Shoot Growth of Garlic. *HortScience*, v. 55:1053-1054. 2020. DOI: <https://doi.org/10.21273/HORTSCI15082-20>.
- Oliveira, R.M., Oliveira, R.A., Botelho, M.E., Galvão, J.C.C., Niero, M.E.S., & Oliveira, J.T. Efeito da Frequência de Irrigação na Absorção de Fósforo na Produção do Milho. *Revista Ibero-Americana de Ciências Ambientais*. v. 12:1-8. 2021. <https://sustenere.co/index.php/rica/article/view/5440>.
- Pinheiro, L.S., Silva, R.C., Vieira, R.C., Aguiar, R.O., Nascimento, M.R., Vieira, M.M., & Silva, P.A. Análise de trilha dos atributos físicos de milho (*Zea mays* L.) em sistema de cultivo convencional. *Research, Society and Development*, v. 10: e8010110832-e8010110832. 2021. DOI: <https://doi.org/10.33448/rsd-v10i1.10832>.
- Resende Neto, G.L., Modesto, A.O., Silva, F.B., & Borhes, D.F. Avaliação do desenvolvimento do milho (*Zea mays* L.) sobre diferentes níveis de compactação no solo. *Revista GeTeC*, v. 14. 2024. <https://revistas.fucamp.edu.br/index.php/getec/article/view/3363>
- Silva, S.B. Análise de Solos. Belém: Universidade Federal Rural da Amazônia. Serviço de Documentação e informação. 150p. 2003. ISBN: 978-85-7295-132-6.

Silva Pinheiro, L., Vieira, M.M., Nunes, G.G.T., da Silva, C.R., Oliveira, J.T., Castro, T.R., & Silva, P.A. Chemical attributes of corn under the path analysis in an Amazon ecosystemic domain. *Revista Engenharia na Agricultura-REVENG*, v. 32(Contínua), p. 37-46. 2024. DOI: <https://doi.org/10.13083/reveng.v32i1.16811>

Singh, S., Nenavath, M. D., Raj, T., & Singh, V. Comparison of Indian corn with The US and South American commodity corn for wet milling starch yields. *Industrial Crops and Products*, 221, 119444. 2024. <https://doi.org/10.1016/j.indcrop.2024.119444>

Souza, F.R.S.D., Ribeiro, P.H.E., Veloso, C.A.C., & Corrêa, L.A. Produtividade e Estabilidade Fenotípica de Cultivares de Milho em Três Municípios do Estado do Pará. *Pesquisa Agropecuária Brasileira*. Brasília-DF, v. 37:1269-1274. 2002. <http://dx.doi.org/10.1590/S0100-204X2002000900010>.

USDA ERS, United States Department of Agriculture-Economic Research Service, Feed Grains Data: Yearbook Table 1 & 3. *Feed Grains Yearbook Data Tables*, ed. 2023.

USDA FAS, United States Department of Agriculture, Foreign Agricultural Service, Data and Analysis, Production – Corn. 2023. <https://fas.usda.gov/data/production/commodity/0440000>.

USDA NASS, United States Department of Agriculture-National Agricultural Statistics Service, Corn: Production by Year, US. 2023.

Vasconcellos, J.P.R., Reis, R.B., Rezende, R.M., Rezende, R.A.L.S., & Carvalho, A.F.S. Influência da velocidade de semeadura na produtividade do trigo. *Revista da Universidade Vale do Rio Verde*, v. 16:1-7. 2019. DOI: <http://dx.doi.org/10.5892/ruvrd.v16i3.5601>.

Vigolo, N., Scherner, A.C.R., Lopes, F.V., Fernandez, J.L.N., de Souza, J.V.V., Ruppim, S.M.C., & Zanin, C.E.C.T. Avaliação de atributos físicos do solo em diferentes tempos de uso no estado de mato grosso. *RECIMA21-Revista Científica Multidisciplinar-ISSN 2675-6218*, v. 5, n.6, e565269-e565269. 2024. DOI: <https://doi.org/10.47820/recima21.v5i6.5269>