

Plantability: sowing depth and operational speed effect on soybean yield

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Received: 23/09/2025; Accepted: 17/12/2025.

ABSTRACT

Soybean (*Glycine max* (L.) Merr.) is a strategic crop for Brazilian and global economies. Plantability performance is crucial for crop establishment and production efficiency, as adequate seed placement, speed, and depth can improve yields. This study evaluated the effects of plantability on soybean performance, focusing on operating speed and sowing depth. The experiment was conducted at a commercial soybean production site in Três Marias, Minas Gerais, Brazil. Treatments included two seed deposition depths (3 and 5 cm) and four operating speeds (5, 7, 9, and 12 km h⁻¹), in a randomized strip-plot design. The variables evaluated were the coefficient of variation of seed distribution (CV%), multiple spacing, missing spacing index, acceptable spacing index, and grain yield. Results showed that operating speed directly influenced acceptable spacing, with the best indices at 5 km h⁻¹. Missed (failed) spacings were more frequent at the 3-cm sowing depth, whereas multiple spacings increased at operating speeds above 7 km h⁻¹ and at the 5-cm sowing depth. The CV% increased linearly with speed. Crop yield decreased with increasing speed and lower sowing depth. Sowing at 5 km h⁻¹ and a sowing depth of 5 cm provided the best balance between acceptable spacing and soybean yield.

Keywords: *Glycine max* (L.) Merr., Sowing quality, Mechanization, Efficiency.

Plantabilidade: efeito da profundidade e velocidade de semeadura na produtividade da soja

RESUMO

A soja (*Glycine max*) é uma cultura estratégica para as economias brasileira e mundial. A plantabilidade é determinante no estabelecimento da lavoura e na eficiência produtiva, pois condições adequadas de velocidade e profundidade de deposição de sementes favorecem maiores rendimentos. Portanto, objetivou-se avaliar a plantabilidade durante a semeadura de soja, especificamente considerando o efeito da velocidade e profundidade de deposição de sementes no desempenho produtivo da cultura. O experimento foi conduzido em uma área comercial de produção de soja no município de Três Marias - MG. Os tratamentos incluíram duas profundidades de deposição (3 e 5 cm) e quatro velocidades operacionais (5, 7, 9 e 12 km h⁻¹), em um delineamento experimental em faixas aleatorizadas. Foram avaliados o coeficiente de variação de semeadura (CV%), índices de espaçamentos múltiplos, falhos e aceitáveis, além da produtividade final. Os resultados mostraram que a velocidade influenciou diretamente os espaçamentos aceitáveis, com melhores índices a 5 km h⁻¹. Os espaçamentos falhos foram mais frequentes na profundidade de 3 cm, enquanto os múltiplos aumentaram em velocidades superiores a 7 km h⁻¹ e com semeadura à 5 cm. O CV% apresentou crescimento linear com a velocidade. A produtividade diminuiu com o aumento da velocidade e com menor profundidade de semeadura. A semeadura à 5 km h⁻¹ na profundidade de 5 cm foi a que promoveu o melhor equilíbrio entre espaçamentos adequados e produtividade.

Palavras-chave: *Glycine max*, Qualidade de semeadura, Mecanização, Eficiência.



1. Introduction

Soybean is an important crop worldwide. It has a high protein content and high-quality oils, making it a key raw material for producing food products and, notably, for the feed industry, where it supports intensive animal protein production. This versatility, combined with strong international demand, positions soybean as a leading agricultural commodity, driving economic and social development in various producing regions (Kumar et al., 2023; Pereira and Brisola, 2022).

In Brazil, soybean expansion has been crucial for strengthening the agricultural sector and consolidating the country as one of the world's largest producers and exporters. The continuous growth of the cultivated area and production reflects not only increasing global demand but also the strategic role of Brazilian agriculture in the international economic landscape. In this context, soybean serves as a central axis connecting food security, foreign exchange generation, and competitiveness in global agricultural trade (Cornacini et al., 2024; Silva et al., 2025).

Sowing plays a fundamental role in soybean production, as stand failures and uneven seed placement can negatively affect crop yield, resulting in financial losses for farmers. Moreover, modern production systems emphasize the sustainability of soybean cultivation, monitoring pollutant emissions during sowing (Martins et al., 2024) and improving the calibration of seeding machinery (Pereira et al., 2021) within the broader concept of plantability.

Plantability is understood as placing the seed at the appropriate time and with proper placement, spacing, and depth, using the necessary care to achieve the maximum crop yield (Filho et al., 2021). According to Martin et al. (2022), sowing is a critical stage in soybean production, as seed placement depth affects plant establishment and uniform emergence, while the operating speed of the mechanized planter influences the uniformity of seed distribution along the planting row.

Barbosa et al. (2021) evaluated the effect of speed on plantability and found that increasing speed reduced the percentage of acceptable spacing and increased spacing irregularities, without significantly affecting grain yield. These findings highlight the importance of adjusting speed and the metering system to optimize the operational efficiency of soybean sowing.

On the other hand, studies conducted in Minas Gerais showed that although the number of seeds per meter was highly precise during soybean sowing, the rates of double plants and skips showed considerable variability. This underscores the importance of periodic machine adjustments and metering system selection (Filho et al., 2020) to optimize sowing uniformity and,

consequently, improve crop efficiency and yield (Silva and Ribeiro, 2025).

Operating speed significantly alters seed distribution. Furthermore, the type of soil preparation can influence seed depth and spacing, affecting soybean grain yield (Siqueira et al., 2024). In this context, it is essential to investigate the optimal operating speed and sowing depth for soybean cultivation. This study aimed to evaluate the effect of plantability on soybean yield, specifically considering operating speed and sowing depth.

2. Material and Methods

The experiment was carried out in a commercial soybean production area at Fazenda Paraíso, in Três Marias, Minas Gerais, Brazil. The site is situated at 18°27'27.06" S and 45°18'4.57" W, at an altitude of 585 m. The climate region is classified as tropical-savanna with dry winters and rainy summers (Aw, Köppen). The mean annual temperature is 24.5 °C, and annual precipitation ranges from 1,250 to 1,350 mm.

The local soil is predominantly classified as Latossolo Vermelho-Amarelo with medium texture. These soils develop mainly over sediments of the Bambuí Group formation (Costa et al., 2019; Resende et al., 2023). For the experiment, a 3,000 m² plot (60 × 50 m) was randomly established within a 100-hectare commercial soybean production area irrigated by a center-pivot system (Figure 1).

Sowing was performed using a set composed of a New Holland T7 205 tractor (225 kW, radial tires) coupled to a Case precision pneumatic planter, model Easy Riser 3216 (manufactured in 2021), with 15 rows and a 50 cm row spacing (Figure 2).

The tractor was equipped with three gear groups (A, B, and C), each with six speeds, for a total of 18 combinations. To set the speed for each treatment, the following configurations were adopted: 5 km h⁻¹ (gear B, 2nd speed); 7 km h⁻¹ (gear B, 3rd speed); 9 km h⁻¹ (gear B, 4th speed); and 12 km h⁻¹ (gear B, 6th speed).

Speed was verified using the tractor's on-board monitor, and fine adjustments were made by regulating engine rotation, which operated between 1,800 and 2,000 rpm. During sowing, the planter opened furrows with a wavy cutting disk and applied fertilizer using a disk unit with depth control. Subsequently, a double-disk sowing unit, also with depth control, deposited the seeds, while a V-shaped covering system performed furrow closure.

For accurate analysis of seed distribution, an Intelliview IV monitor (New Holland) connected to the ISOBUS system (Agrosystem) was used, allowing the recording of the number of seeds per linear meter, the quantity of seeds deposited in the soil, and possible metering failures.

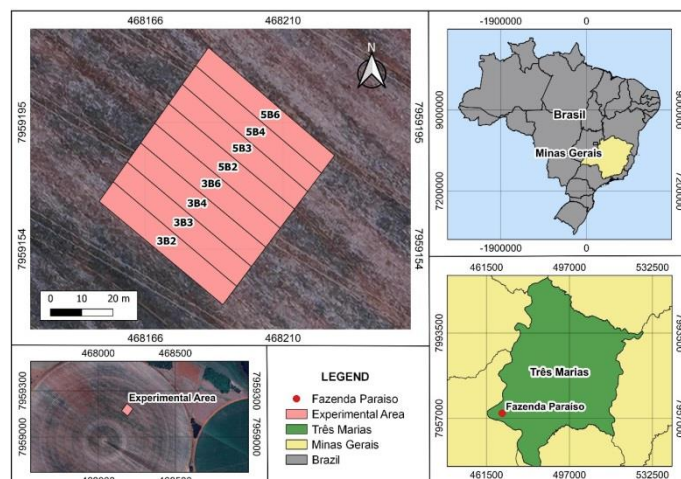


Figure 1. Detailed description of the research region and data collection area. The initial number (3 or 5) refers to the sowing depth; the letter in the middle corresponds to the tractor's gear group (A, B, or C); and the final number indicates one of the speeds within that gear group.



Figure 2. (a) New Holland T7 tractor and (b) Case Easy Riser 3216 planter.

Fertilizer distribution was carried out using a Fertisystem Auto Lub Ap Ng distributor equipped with a transmission gear, an auger, and an inspection cover. No additional monitors or sensors were used; supervision was performed directly by a technician who checked the operation of the augers throughout the process. The seed metering device was a Promax disk with 56 holes, suitable for the seed size employed and recommended for the soybean crop.

For soil characterization, deformed samples were collected at 50 randomly distributed points within the experimental area at a depth of 20–40 cm. Soil analysis revealed the following average chemical characteristics of the plot: pH 5.58; residual phosphorus 13.17 mg dm⁻³; available phosphorus 4.15 mg dm⁻³; potassium 64.93 mg dm⁻³; calcium 1.88 cmol_c dm⁻³; magnesium 0.65 cmol_c dm⁻³; aluminum 0.20 cmol_c dm⁻³; sum of bases 2.70 cmol_c dm⁻³; effective cation exchange capacity (CTC t) 2.90 cmol_c dm⁻³; cation exchange capacity at pH 7.0 (CTC T) 5.61 cmol_c dm⁻³; base saturation (V%) 47.39; and aluminum saturation (m) 8.08%.

Soil preparation included applying gypsum across the entire cultivated area using a JAN 6000 soil conditioner spreader equipped with belts and rotating disks. The experimental area was managed under a corn–soybean–oat crop rotation system during the 2020–2021 and 2021–2022 seasons. The soybean cultivar used was a 7709 Nidera type, with 99% purity, 92% germination, and 87% vigor, a recommended population of 300,000 plants ha⁻¹, and an estimated growth cycle of 105 days. Soil correction and fertilization were carried out according to the soil analysis and the recommendations of the 5th Approximation for the state of Minas Gerais.

The phytosanitary treatment of the seeds and the herbicide control applications and pesticides were carried out with the following products: glyphosate (3 L ha⁻¹); Methomyl (1 L ha⁻¹); TA 35 ultra 0.15 (L ha⁻¹); Ignus (0.5 L ha⁻¹); Potamol (0.1 L ha⁻¹) and Freno (0.6 L ha⁻¹). Applications followed commercial management and technical recommendations adopted in the field for all treatments, totaling ten applications throughout the soybean cycle.

To reduce seed damage and promote seed flow in the metering device, 4 g of graphite was applied per kilogram of treated seeds, and the planter was adjusted to operate at a vacuum pressure of 124.10 kPa in the metering suction lines. Simultaneously, in-furrow treatment was applied using a Micron system at an application rate of 25 L ha⁻¹, employing the following products and respective doses: Radicel (150 mL ha⁻¹), Glock (60 mL ha⁻¹), an *Azospirillum*-based inoculant (200 mL ha⁻¹), and a soybean inoculant (225 mL ha⁻¹).

The experimental design consisted of a randomized strip-plot scheme, with each strip measuring 50 m in length and 7.5 m in width, for a total of 8 strips. Treatments were arranged as a combination of two sowing depths (3 and 5 cm) and four operating speeds (5, 7, 9, and 12 km h⁻¹). The response variables evaluated were the coefficient of variation of seed distribution (CV%), multiple spacing index (ID), missing spacing index (IF), acceptable spacing index (IA), and final grain yield. In each experimental unit, 20 plants were evaluated, and the experiment included four replications.

To determine the indices of acceptable, multiple, and missing spacing, the methodology described by Kurachi et al. (1993) was applied. Sowing quality data were subjected to parametric statistical analysis, starting with the Shapiro–Wilk normality test, followed by analysis of variance (ANOVA) and, when applicable, mean comparisons using Tukey's test at a 5% probability level. Additionally, linear regression was applied to assess trends of the variables as a function of the treatments. All analyses were performed using R statistical software.

3. Results and Discussion

Sowing depth and operating speed in soybean cultivation are key factors for optimizing grain yield and ensuring uniform plant distribution (Pereira et al., 2021). In this study, the influence of these variables was evaluated, considering two sowing depths and four operating speeds. Operating speed and sowing depth were significant in the soybean planting process; however, operating speed had the greatest impact on the parameters evaluated.

At a speed of 5 km h⁻¹, an average of 12.67 plants per meter of row with acceptable spacing was recorded, whereas at 9 km h⁻¹ this value decreased to 9 plants (Figure 3). Sowing depth, however, showed no significant effect on the number of plants with acceptable spacing, suggesting that the different sowing speeds did not influence this factor.

Souza and Lazaretti (2022) reported that sowing speeds between 6 and 9 km h⁻¹ do not significantly affect plant spacing within crop rows. However, an increase in missing spacings during sowing leads to greater

unevenness in seed distribution, resulting in deficiencies in the final stand (Dalla et al., 2018). In addition, an incorrect seed metering mechanism can reduce planting uniformity (Filho et al., 2020), highlighting the importance of adjustments during machine preparation to achieve adequate plantability.

The negative slope obtained in the linear regression between operating speed and the acceptable spacing index, with a correlation coefficient of $r = 0.66$, indicates that this index tends to decrease as speed increases. No significant statistical differences were observed among the speeds of 5, 7, and 12 km h⁻¹, whereas the speed of 9 km h⁻¹ showed the lowest values of acceptable spacing.

Figure 4 shows that no significant differences were observed in the missing spacing index across different sowing speeds. However, when considering seed placement depth, sowing at 5 cm resulted in a lower missing spacing index than at 3 cm, with an average reduction of 1.5 in this index.

The results obtained differ partially from those reported in the literature, which indicate that higher operating speeds tend to compromise the efficiency of the seed metering systems (Wang et al., 2023). In this study, factors such as field quality and the seedbed uniformity likely contributed to minimizing the missing spacing index at all evaluated speeds. Additionally, the planters equipped with advanced technology and adequate soil-adjustment devices facilitated uniform seed distribution at higher operational speeds.

Similar to our findings, Siqueira et al. (2024) obtained better longitudinal seed distribution indices at 3.4 km h⁻¹, but the highest soybean grain yield occurred at speeds close to 6.8 km h⁻¹. The authors believe that higher speeds may reduce the soil pressure exerted by the seed metering mechanism, thereby improving the initial establishment of the crop.

In contrast, Petrovic et al. (2025) reported that increasing sowing speed is associated with increased missing spacing index, mainly due to reduced efficiency of seed metering mechanisms at high speeds. The occurrence of missing spacings during sowing can promote weed establishment and proliferation by increasing sunlight availability between plants, potentially reducing crop yield and increasing management costs (Gómez-Gómez, 2024).

The lowest multiple spacing index was observed at 5 km h⁻¹, while treatments at 7, 9, and 12 km h⁻¹ showed a higher multiple spacing index (Figure 5). As for sowing depth, a higher multiple spacing index was recorded at 5 cm compared with 3 cm. These results are consistent with those reported by Mantovani et al. (2021), who documented a significant increase in the multiple spacing index at speeds above 10 km h⁻¹ compared with 4 km h⁻¹, highlighting the influence of sowing speed on seed distribution uniformity.

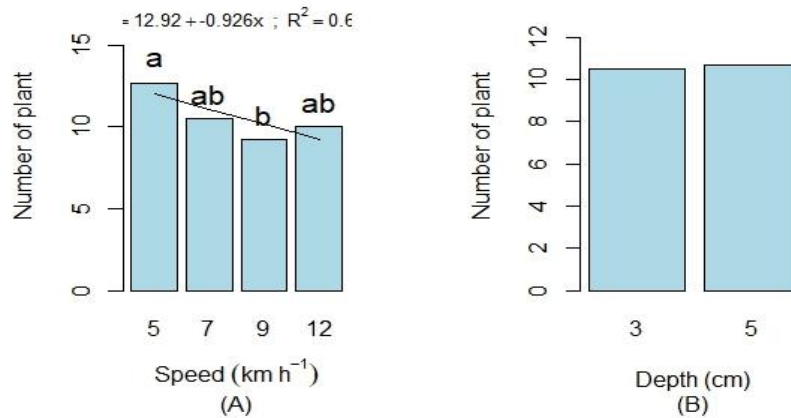


Figure 3. Number of plants within acceptable spacing according to different sowing speeds (A) and sowing depths (B). *Means followed by the same letter do not differ statistically according to Tukey's test ($p \leq 0.05$). CV = 23.96%. *ns = not significant ($p \leq 0.05$).

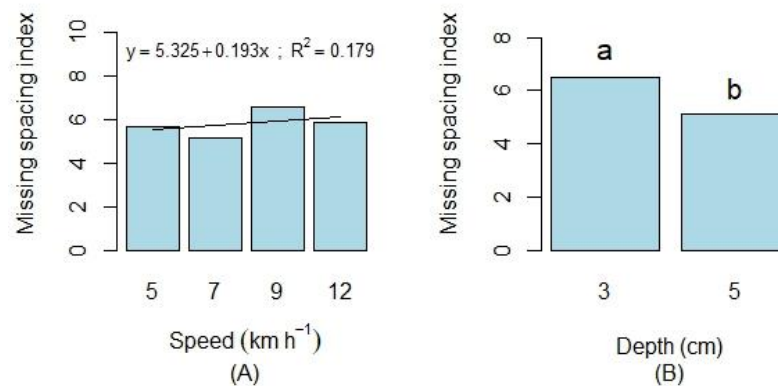


Figure 4. Missing spacing index per treatment according to different sowing speeds (A) and sowing depths (B). *Means followed by the same letter do not differ statistically according to Tukey's test ($p \leq 0.05$). CV = 36.95%. *ns = not significant ($p \leq 0.05$).

Increasing operating speed can be associated with a higher failure index, as evidenced by the positive regression slope (Pearson correlation coefficient = 0.54). This condition causes greater variability in seed furrow deposition (Pereira et al., 2021), resulting in uneven soybean growth, a higher probability of failures, and difficulty with phytosanitary management (Pereyra et al., 2022; Versendaal et al., 2024).

The coefficient of variation of seed distribution (CV%) was significant at speeds above 7 km h⁻¹ but showed no significant influence on sowing depth (Figure 6). The water availability in the area under center pivot irrigation may have minimized the differences between depths. This occurs because sowing in an irrigated area can protect seeds from water stress or drought soon after sowing. In our research, irrigation control may have favored adequate emergence at both depths.

The highest coefficients of variation were observed at speeds above 7 km h⁻¹, with the lowest value recorded at 5 km h⁻¹, which was 51.2%. Lenhardt et al. (2022) reported that increasing planter speed generates greater operational variability, leading to irregular plant distribution and establishment problems. In our study,

plant population was not significantly affected by either sowing speed or depth (Figure 7).

In addition to speed, several factors can significantly influence plant population, including seed quality and uniformity, planter accuracy, sowing depth, and environmental conditions such as soil moisture, temperature, and salinity (Conceição et al., 2023). According to Figure 7(B), the highest plant density was recorded at an operating speed of 9 km h⁻¹, with 14.33 seeds per meter of row, a value close to the initially planned 15 seeds per meter.

According to Villamar and Celi (2024), higher sowing density can increase crop yield but also increase competition for resources, potentially negatively affecting plant growth. In line with this, the present study did not observe a significant effect of speed on average plant population, as indicated by the coefficient of determination ($R^2 = 0.0004$), although a slight tendency of reduced stand with increasing operating speed was evident, reflected in the negative regression slope.

The results indicate that both increasing operating speed and variations in sowing depth affected the sowing quality indices.

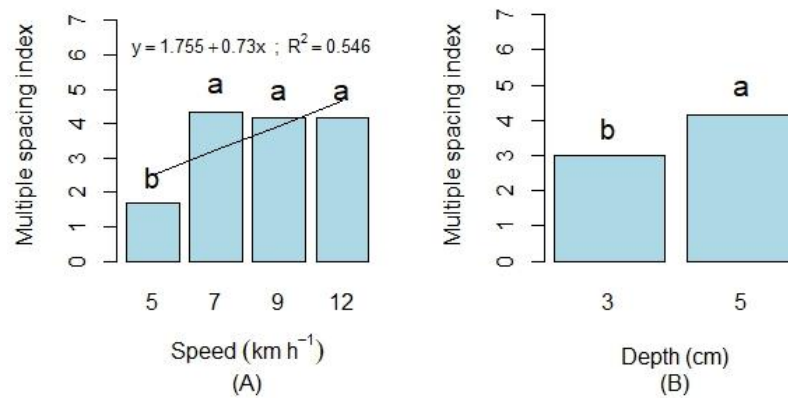


Figure 5. Multiple spacing index per treatment according to different sowing speeds (A) and sowing depths (B). * Means followed by the same letter do not differ statistically according to Tukey's test ($p \leq 0.05$). CV = 42.28%. *ns = not significant ($p \leq 0.05$).

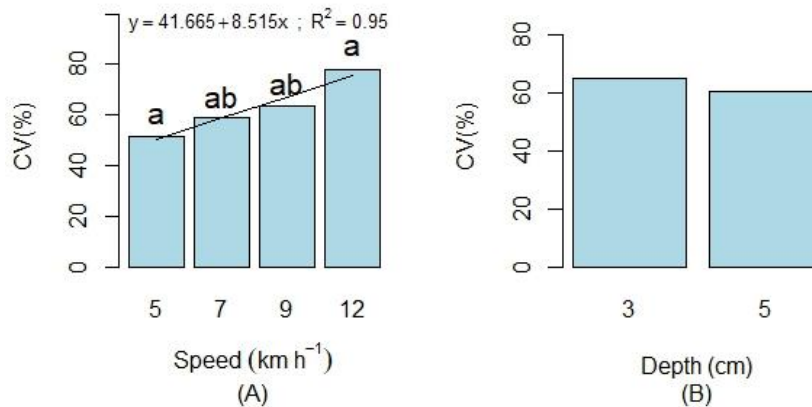


Figure 6. Coefficient of variation of seed distribution (%) for different sowing speeds (A) and sowing depths (B). *Means followed by the same letter do not differ statistically according to Tukey's test ($p \leq 0.05$). CV = 34.73%. *ns = not significant ($p \leq 0.05$).

Regarding soybean yield at different depths, sowing at 5 cm depth achieved an average of 5.51 t ha⁻¹, higher than at 3 cm (5.25 t ha⁻¹) (Figure 8B).

These results are consistent with those reported by Gomides et al. (2023), who, evaluating sowing depths of 2, 4, 6, 8, and 10 cm, observed significant increases in plant height and demonstrated that at 6 cm, stem diameter was 35.7% higher than in plants sown at 10 cm.

Similarly, the same authors reported that at 4 cm, the

number of pods per plant increased by 11.14% compared to sowing at 8 cm, while soybean production was 6% higher when sown at 6 cm than at 4 cm. Consistently, Balestrin et al. (2020) reported a 16.9% increase in plant emergence at 5 cm compared to 2 cm, and an 11% increase compared to 10 cm, corroborating the decisive effect of sowing depth on establishment, physiological quality, and crop yield. Regarding sowing speed and its effect on soybean yield, the results show an opposite trend to that observed for sowing depth.

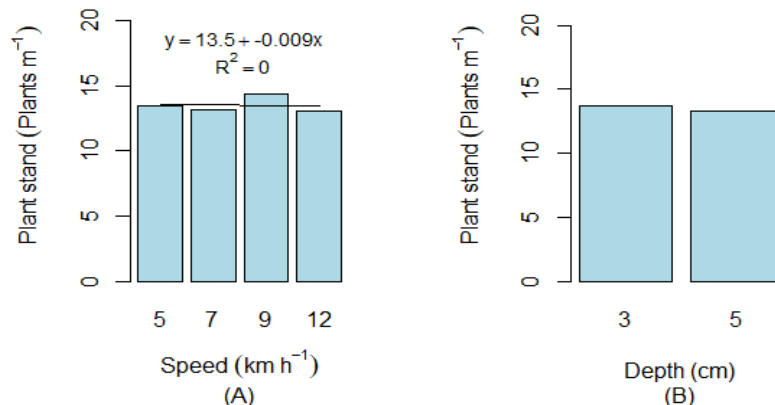


Figure 7. Plant stand according to different sowing speeds (A) and sowing depths (B). *Means followed by the same letter do not differ statistically according to Tukey's test ($p \leq 0.05$). CV = 9.08%. *ns = not significant ($p \leq 0.05$).

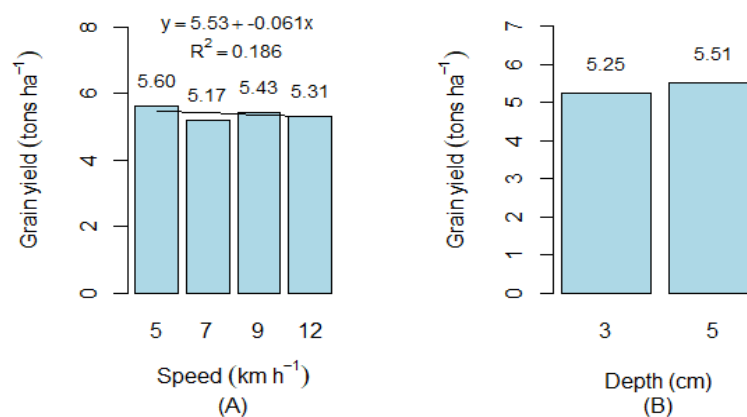


Figure 8. Soybean grain yield according to different sowing speeds (A) and sowing depths (B).

Although no statistically significant differences in yield were detected among speeds, an increase in grain yield was recorded at 5 and 9 km h⁻¹ (Figure 8A). This behavior suggests that lower speeds may optimally promote soybean growth by ensuring adequate seed spacing without compromising sowing uniformity.

Thus, the yield increase at 5 km h⁻¹ was 7.6%, 3.15%, and 5.3% compared to speeds of 7, 9, and 12 km h⁻¹, corresponding to differences of 0.43, 0.18, and 0.30 t ha⁻¹ for the respective speeds. Accordingly, the average yield gain when working at 5 km h⁻¹ is 0.30 t ha⁻¹. Compared with the direct yield gain due to sowing depth (0.26 t ha⁻¹), the results show that the variables speed and depth are equally significant for soybean sowing quality.

Our findings are consistent with those reported by Mota and de Lima (2025), who observed that an increase in planter travel speed is associated with a significant rise in the missing spacings (9%) and multiple spacings (5%) when operating at speeds above 6 km h⁻¹, reducing sowing uniformity and, consequently, grain yield. These authors also reported that at a speed of 4 km h⁻¹, yield was 2.7% higher compared to 6 km h⁻¹, and that from 10 km h⁻¹ onward, yield decreased by 2.3% for every 2 km h⁻¹ increment in sowing speed.

New agricultural traffic management systems can improve sowing quality and reduce the environmental impact (Martins et al., 2024). Moreover, machine and tractor adjustments are expected to modernize future grain production operations (Lanças et al., 2024), helping to achieve new levels of sustainability and efficiency in crop establishment.

4. Conclusions

The study demonstrated the effect of planting quality (plantability) on soybean yield. Operating speed and sowing depth were significant factors in this study. The main conclusions are as follows:

Operating speed significantly reduced the number of acceptable spacings, whereas sowing depth showed no significant effect on this variable.

Increasing operating speed did not influence the missing spacing index, while sowing depth had a significant effect, with higher missing spacing index values at shallower depths.

The double-spacing index was significantly affected by both speed and depth. The lowest double-spacing values were observed at lower speeds and greater sowing depths.

Missing spacings were more frequent at a depth of 3 cm, while multiple spacings increased at speeds above 7 km h⁻¹ and at a sowing depth of 5 cm.

Crop yield decreased with increasing speed and shallower sowing depth.

Lower operating speeds reduced the missing spacing index and increased soybean grain yield. An operating speed of 5 km h⁻¹ and a sowing depth of 5 cm showed the best relationship between adequate spacing and soybean yield.

Authors' Contribution

All authors contributed to the conception and preparation of this manuscript. David Rattes de Andrade Carvalho, Jordan Alexis Castillo Coronado, Luis Henrique Palhão, Lucas Leite Doerl, Henrique Canestri Rafael, and Aldir Carpes Marques Filho participated in data analysis, manuscript writing, and critical revision. David Rattes de Andrade Carvalho and Aldir Carpes Marques Filho were responsible for conducting the experiment and collecting the data.

Bibliographic References

Balestrin, J.T., Frandaloso, D., Casagrande, R., 2020. Influência do tratamento de sementes e da profundidade de semeadura na emergência de plântulas de soja e feijão

- Brazilian Journal of Development, 6(7), 49804-49810. <https://doi.org/10.34117/bjdv6n7-579>
- Barbosa, F.F.J., Muncio, C.A., Pereira, F.W.J., Vieira, J.M., Macedo, L.L., Rosa, N.N.D., 2021. Qualidade da sementeira de soja em função da velocidade do trator-semeadora e disco dosador de sementes. *Society and Development*, 10 (2), 1-10. <http://dx.doi.org/10.33448/rsd-v10i2.12723>
- Conceição, A.E.D., Reges, N.P.R., Santos, M.P., 2023. Influência do vigor, diâmetro da semente e profundidade de sementeira no estabelecimento inicial da soja. *Society and Development*, 12 (2), e27412240260. <http://dx.doi.org/10.33448/rsd-v12i2.40260>
- Cornacini, F.R., Ribeiro, S.R.N., Bouças, F.J.R., 2024. Soybean Yield Losses Related to Drought Events in Brazil: Spatial–Temporal Trends over Five Decades and Management Strategies. *Agriculture*, 14(12), 2144. <https://doi.org/10.3390/agriculture14122144>
- Costa, L.F., Bento, C.C., Heinrich, H.A., Baggio, F.H., 2019. A spacial analysis of organic matter, oxides and granulometric distribution on sediments as a support for geochemical analysis on Três Marias reservorio – Minas Gerais. *Geochimica Brasiliensis*, 33(4), 358-369. 10.21715/GB2358-2812.2019334358
- Dalla C.R., Ozecoski, J., Lajús, C.R., Cericato, A., 2018. Influência da velocidade de sementeira no coeficiente de variação e no estabelecimento do milho. *Anuário Pesquisa e Extensão Unoesc São Miguel Do Oeste*, 3, e17787. <https://periodicos.unoesc.edu.br/apeusmo/article/view/17787>
- Filho, A.C.M., Rusconi, L.H., Silva, P.R.A., 2020. Plantabilidade e distribuição longitudinal de sementes de algodão com diferentes conjuntos disco-anel em dosador mecânico. *Energia na agricultura*, 35 (4), 476-483. <https://doi.org/10.17224/EnergAgric.2020v35n4p476-483>
- Filho, A.C.M., Ventura, H.C. 2021. Can sowing speed affect corn yield? *Revista De Agricultura Neotropical*, 8 (3), e6486-e6486. <https://doi.org/10.32404/rean.v8i3.6486>
- Gómez-Gómez, R., 2024. Weeds or several vegetation? A concept proposal for their agroecological management. *Agronomía Mesoamericana*, 35 (1), 56900 <https://doi.org/10.15517/am.2024.56900>
- Gomides, J.F.B., Martins, M.B., Bortolheiro, F.P.A.P., Seron, C.C., Salles, J.S., Vendrusculo, E.P., 2023. Soybean grain yield is impacted by the sowing depth and the type of soil cover. *Revista de Agricultura Neotropical*, 10 (4), e7470. <https://doi.org/10.32404/rean.v10i4.7470>
- Kumar, B.S., Kumar, G.R., Eriksson, M., Lagerkvist, C., 2023. The distortion in the EU feed market due to import constraints on genetically modified soy. *Agricultural and Food Economics* 11, (50), 2-26. <https://doi.org/10.1186/s40100-023-00290-7>
- Kurachi, S.A.H., Costa, J.A.S., Bernardi, J.A., Coelho, J.L.D., Silveira, G.M., 1993. Avaliação tecnológica: resultados de ensaios de mecanismos dosadores de sementes de semeadoras e adubadoras de precisão, IAC, Boletim científico, 28(1), 237-245. <https://doi.org/10.1590/S0006-87051989000200011>
- Lenhardt, E.R., Feldmann, N.A., Mühl, F.R., Cassol, S.P., 2022. Influência de diferentes velocidades de sementeira na produtividade da soja. *Revista Inovação - Gestão e Tecnologia no Agronegócio*, 1, 1 - 15. <http://revistas.uceff.edu.br/inovacao/article/view/13/3>
- Mantovani, A., Nascimento, J., Arcoverde, S.N., Secretti, M.L., 2021. Mecanismos sulcadores e velocidade de sementeira na plantabilidade e produtividade da soja. *Revista Brasileira de Agropecuária Sustentável*, 11 (1), 36-42. <https://periodicos.ufv.br/rbas/article/view/12005>
- Laças, K.P., Marques Filho, A.C., Santana, L.S., Ferraz, G.A.S., Faria, R.O., Martins, M.B. 2024. Agricultural Tractor Test: A Bibliometric Review. *AgriEngineering*, 6, 2229–2248. <https://doi.org/10.3390/agriengineering6030131>
- Martin, T.N., Burg, G.M., Cunha, V.S., Pinho, M.A.B., Pires, J.L.F., Vey, R.T., 2022. Ecologia, fisiologia e práticas culturais: plantabilidade e velocidade de sementeira na cultura da soja. Em: Martin, T.N., Pires, J.L.F., Vey, R.T. (Ed.), *Tecnologias aplicadas para o manejo rentável e eficiente da cultura da soja*. Santa Maria: GR, págs. 201-214.
- Martins, M.B., Marques Filho, A.C., Seron, C.D.C., Guimarães Júnnyor, W.D.S., Vendrusculo, E.P., Bortolheiro, F.P.A.P., Santana, L.S., 2024. Controlled Traffic Farm: Fuel Demand and Carbon Emissions in Soybean Sowing. *AgriEngineering*, 6 (2), 1794-1806. <https://doi.org/10.3390/agriengineering6020104>
- Mota, M.C., Lima, O.N., 2025. Effect of seeding speed and graphite lubricant on soybean plantability. *Revista Brasileira de Engenharia Agrícola e Ambiental*, 29 (3), e281566. <http://dx.doi.org/10.1590/1807-1929/agriambi.v29n3e281566>
- Pereira, J.C., Filho, A.C.M., Souza, F.L.P., Silva, P.R.A., 2021. Plantability and influence of the application of graphite associated with the chemical treatment of soybean seeds. *Revista de Agricultura Neotropical*, 8 (3), e5997-e5997. <https://doi.org/10.32404/rean.v8i3.5997>
- Pereira, B.M., Brisola, M.V., 2022. Techno-economic Evolution of Soybean Production in Brazil and Argentina. *Journal of Agricultural Science*, 14 (8). <https://doi.org/10.5539/jas.v14n8p145>
- Pereyra, V.M., Bastos, L.M., Borja, R.A.F., Melchiori, R.J.M., Maltese, N.E., Appelhans, S.C., Vara, P.P.V. Wright, Y., Brokesh, E., Sharda, A., Ciampitti, I.A., 2022. Early-season plant-to-plant spatial uniformity can affect soybean yields. *Scientific Report*, 12 (1), 17128. <https://doi.org/10.1038/s41598-022-21385-z>
- Petrovic, I., Vučajnk, F., Trdan, S., Bernik, R., Vidrih, M., 2025. The influence of plating speed of a maize vacuum planter on plant spacing variability and ear parameters. *Agronomy*, 15 (2), 462. <https://doi.org/10.3390/agronomy15020462>
- Resende, C.G., Palucci, R.G., Furtado, C.M.L., Paranaíba, B.G.M., Ferreira, S.F.M., Arantes, K.V., Costa, N.D., 2023. Relação solo-ambiente em área degradada por voçoroca no Triângulo Mineiro, Minas Gerais. *Revista Brasileira de Geomorfologia*, 24(3), 1-17. <http://dx.doi.org/10.20502/rbg.v24i3.2384>

Silva, B.P., Cassei, R.A., Wachs, P., Lacerda, D.P., Saurin, T.A., 2025. Sustainability and the soybean supply chain in Brazil: challenges and implications through the lens of the current reality tree. *Brazilian Journal of Operations and Production Management*, 22 (2), 1-24. <https://doi.org/10.14488/BJOPM.2396.2025>

Silva, S.E., Ribeiro, K.D., 2025. Eficiência da semeadura de soja avaliada através da plantabilidade com diferentes semeadoras. *Contemporary Journal*, 5 (1), 1-18. <https://doi.org/10.56083/RCV5N1-088>

Siqueira, A.C.S., Geremias, T.K.C., Machado, T.A., 2024. Soybean plantability in different operating conditions. *Revista Agroambiente On-line*, 18(1), 1-15. <https://doi.org/10.18227/1982-8470ragro.v18i00.7825>

Souza, F.S., Lazaretti, N.S., 2022. Características biométricas da soja em função de diferentes velocidades de semeadura. *Cultivando o saber*, 15, 129-137. <https://cultivandosaber.fag.edu.br/index.php/cultivando/article/view/1139>

Versendaal, E., Pereyra, V.M., Irby, T., Kovacs, P., Hefley, T., Vara, P.P.V., Kyveryga, P., Woestyne, B.W.V., Ciampitti, I.A., 2024. Soybeanyield and seed quality in equidistant versus non-equidistant plant arrangements under different densities. *Crop Science*, 65 (1), 1-14. <https://doi.org/10.1002/csc2.21364>

Villamar, R.J.A., Celi, S.K.D., 2024. Estudio del cultivo de soya (*Glycine max*) con diferentes densidades de siembra, en el recinto san francisco del tramoso – cantón Quinindé. *Reincisol*, 3 (6), 6607–6623. [https://doi.org/10.59282/reinciso1.V3\(6\)6607-6623](https://doi.org/10.59282/reinciso1.V3(6)6607-6623)

Wang, C., Yang, H., He, J., Kang, K., Li, H., 2023. The influence of seed variety and high seeding speed on pneumatic precision seed maturing. *Engenharia Agrícola*, 43 (3). <https://doi.org/10.1590/1809-4430-Eng.Agric.v43n3e20220183/2023>