Siega *et al.*
Cerrado: Agricultural and Biological Research, 1(2), 21-29, 2024
https://doi.org/10.14295/cerrado.v1i2.613

REVIEW

Influence of planting speed on emergency uniformity and distribution of soybean plants

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Article history
Received: May 06, 2024
Revised: May 28, 2024
Accepted: June 11, 2024

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Abstract: Soybean is a crop of great economic importance, and the efficiency of its production depends on various agronomic factors, among which planting speed stands out due to its direct impact on seedling emergence and plant arrangement in the field. The main objective of this research is to analyze how different planting speeds affect the uniformity of plant emergence and the regularity of plant distribution. To achieve this objective, a comprehensive literature review was conducted, including previous studies that investigated the relationship between planting practices and soybean crop performance. The review results indicated that higher planting speeds tend to impair emergence uniformity due to seed damage and reduced deposition accuracy. This results in uneven emergence and irregular plant distribution, which can compromise homogeneous plant development and reduce yield. On the other hand, lower speeds provide more uniform emergence and more regular distribution, optimizing the use of resources such as light, water, and nutrients. It is concluded that reducing planting speed can significantly improve the uniformity of emergence and distribution of soybean plants, contributing to more efficient and higher-yielding production. It is recommended that producers adjust planting speed according to the specific conditions of their fields to maximize productive potential.

Keywords: Planting speed; Plant distribution; Soybean; Agricultural productivity.

1. Introduction

Soybean (*Glycine max* L. (Merril)) is recognized for its grains abundant in oils and proteins, enjoying a wide range of uses in human and animal nutrition, in addition to its contribution to biofuels and other applications (Pereira et al., 2017; Pinto et al., 2018; Barbosa et al., 2019). Due to its versatility and widespread use, soybeans have emerged as one of the most significant commodities globally, playing a crucial role in agriculture and the economy on a global scale (Rigo et al., 2015).

According to Embrapa (2021), Brazil is the largest soybean producer in the world, second only to the United States (USA). The current importance of this crop, in terms of cultivated area and productivity, is the result of a combination of factors, including improved cultivars and varieties, its broad adaptability and resistance and/or tolerance to biotic and abiotic factors.

A crucial factor for the proper establishment of soybean plants is correct management during sowing operations. To ensure an adequate number of plants, it is essential to create favorable conditions for seed germination and emergence. This includes ensuring the presence of soil moisture and aeration, ensuring adequate contact between the seeds and the soil, and using seeds of high physiological and sanitary quality

(Embrapa, 2011; Ortel et al., 2020).

Regardless of the cultivation system chosen, sowing must promote rapid and uniform plant establishment. This process involves a series of operations, such as cutting the straw, opening furrows in the soil, dosing and distributing seeds and fertilizers in the corresponding furrows, covering the seeds and fertilizers, and adequately compacting the soil. The seeder fertilizer must guarantee a uniform longitudinal distribution of seeds, soil coverage, and a uniform depth of deposition (Jasper et al., 2011; Souza et al., 2019).

Ensuring such conditions provides an ideal environment for the seeds to absorb water and meet the necessary temperature and oxygen requirements to begin the germination process (Souza et al., 2019). The predetermined characteristics of the seeding machine play a crucial role in this process. The mechanisms for cutting and opening the soil, the devices for depositing seeds in the furrows, the pressure applied to the soil by the compacting wheel, the sowing speed, and the distribution of seeds per meter are factors that can directly influence the quality of sowing and the initial development of culture (Weirich Neto et al., 2015).

To achieve ideal sowing quality, it is essential to consider several operational factors, including the furrowing mechanisms of the seeders, the travel speed, and the sowing depth (Souza et al., 2019).

Selecting the correct speed for the tractor-seeder-fertilizer set is essential to maximize productivity. The definition of this operational factor is crucial to guarantee the adequate implementation of soybean cultivation. A careful balance between travel speed and the effectiveness of furrowing and seed deposition mechanisms is essential to ensure uniform seed distribution and consistent seeding depth, resulting in a uniform and healthy plant stand (Santos et al., 2017).

Along with these aspects, the type of furrowing mechanism used by the seeder to deposit the seeds can impact not only the operational performance of the mechanized sets but also the sowing depth, the seed germination rate, and the population density of the plants, especially in direct planting systems (Souza et al., 2019).

Given this, what is the influence of planting speed on the emergence uniformity, and distribution of soybean plants, as described in current scientific literature? It is believed that planting speed has a significant impact on the emergence uniformity and distribution of soybean plants, which can directly affect crop productivity.

The review of this literature is essential to synthesize existing knowledge about the relationship between planting speed and the uniformity of emergence and distribution of soybean plants. Understanding the findings and trends present in the scientific literature can provide valuable guidance for farmers, researchers, and professionals in the agricultural sector, contributing to improving planting practices and increasing soybean productivity (Pokhariyal et al., 2023).

Given this, the objectives of this work are to analyze existing studies on the influence of planting speed on the uniformity of emergence and distribution of soybean plants, to summarize the evidence on the relationship between planting speed, uniformity of emergence, and distribution of soybean plants and propose practical recommendations based on the conclusions of the literature review.

2. Material and Methods

2.1. Systematic review

The study is a systematic literature review to investigate the influence of planting speed on the uniformity of emergence and distribution of soybean plants. Considering the importance of planting speed as one of the main factors that can impact the effectiveness of sowing and, consequently, crop productivity, this study aims to analyze the scientific literature on the arrangement of equipment on this topic.

To select articles to be included in this review, the following criteria will be adopted: Articles published in peer-reviewed scientific journals in the last 25 years (2000-2024); studies that investigate the influence of planting speed on soybean sowing; research that evaluates the uniformity of emergence and distribution of soybean plants about planting speed; articles written in Portuguese, English, and Spanish.

The following criteria were applied to exclude articles: studies that are not directly related to the influence of planting speed on soybean sowing; works that do not address emergence uniformity or distribution of soybean plants as variables of interest; conference reports, conference abstracts and dissertations/theses and articles in languages other than Portuguese, English or Spanish.

The research will be conducted in the following electronic databases: PubMed, Scopus, Web of Science, and Google Scholar. The search terms used will include combinations of keywords such as "soybean planting speed", "planting speed influence", "emergence uniformity", and "plant distribution", among other related terms. Articles cited in the references of selected studies will also be considered to ensure a comprehensive approach.

After carrying out the initial search, articles will be selected based on the established inclusion and exclusion criteria. Titles and abstracts will be initially evaluated to determine the relevance of the study. Then, the selected articles will be read in full and critically analyzed to extract relevant information about the influence of planting speed on the uniformity of emergence and distribution of soybean plants. The results of the selected studies were synthesized and presented in a clear and organized way.

3. Bibliographic review

3.1. Soybean culture

Glycine max (L.) Merrill. is an oilseed plant species of great importance in the world, both for agribusiness and for the human and animal diet. Soy has significant levels of protein (41%), oil (24%), carbohydrates (35%), unsaturated fats (81%), has no cholesterol, and continues to be one of the most important legumes among crops grown in tropical and subtropics around the world (Mangena, 2020; Kim et al., 2023).

The soy we know today has undergone major genetic modifications. Previously, soybean plants were low-growing, and their place of origin was recorded on the East Asian coast, especially near the Yangtze River, in China (Embrapa, 2011; Tamang et al., 2022).

According to Brandalizze (2017), when soybeans entered the West, they first began in places with latitudes similar to their center of origin, starting in Europe in 1712. The first report of the culture in the USA was in 1765, and it slowly developed technologically, between cultivation and research, which resulted in productive, resistant, and adaptable cultivars.

In 1882, soybeans were planted in Brazil for the first time, especially in the state of Bahia. However, without success, due to genetics developed for cold and temperate climates, in 1891 some cultivars were tested at the Agronomic Institute of Campinas (IAC-SP), although there was a success only in the Rio Grande do Sul region between 1920 and 1940 (Brandalizze, 2017; Melo et al., 2020).

Among the economic activities that have seen the most significant growth, soybean production has stood out over the last few decades, where several factors contributed to this expansion. Currently, the soybean market is solid and developed nationally or internationally, with significant protein values, generation of technologies, and also commercial products of animal and vegetable origin (Hirakur; Lazzarotto, 2014; Silva et al., 2020).

Due to the increase in agricultural cultivation areas related to the need for productive increases in grain crops already existing in Brazil, it is essential to search for new solutions that aim to improve productivity levels and reduce production costs (Cavalcante et al., 2020; Maraschin et al., 2020).

The methodology for describing the phenological stages of soybean crops proposed by Brandalizze (2017) is the most used today and can be applied to any cultivar. The authors divided the development of soybean plants into two groups: vegetative and reproductive stages, represented by V and R, respectively, followed by a numerical index as a reference for a given phase, except for the VE and VC stages corresponding to the emergency and vegetative stages of cotyledons, respectively. During the crop cycle, plants are subject to dealing with environmental conditions that are not optimal for their full development, known as biotic and abiotic stresses (Santos, 2020; Neto et al., 2023).

The air temperature where soybeans grow and develop best is between 20 °C and 30 °C. Likewise, the ideal soil temperature range is also between 20 °C and 30 °C. For quick and uniform germination, the depth of the hole should be equal to 5 cm and the optimum planting temperature should be 25 °C. Sowing at soil temperatures below 20 ºC can compromise germination and post-germination seedling development (Farias et al., 2016; Melo et al., 2020; Neto et al., 2023).

3.2. Soybean distribution

Uniformity in the distribution of seeds in the soil has been highlighted as a strategy to increase the productivity of certain crops (Pinheiro Neto et al., 2008). To guarantee this regularity, the machine's travel speed is a parameter of great importance. The plant stand can be affected by the operating speed of the machine at planting time, resulting in lower productivity. Speed can influence wheel slippage, when the soil is not at field capacity, speed of the seed distributing mechanism, distance, depth and seed exposure, seed doubling, and mechanical damage (Garcia et al., 2011; Rinaldi et al., 2023).

Another factor in the tractor-seeder set is that speed influences fuel consumption (Furlani et al., 2005). The difference in seed size does not directly influence the distance between seedlings when carried out at recommended speeds. However, when planting speed values increase, the size of the seeds can influence, causing a smaller population and greater distances between seedlings (Rosales, 2000).

3.3. Seed distribution mechanisms

Grain production, based on sustainable practices, demands the continuous improvement of agricultural equipment, which seeks greater efficiency and precision. Seeders play a crucial role in this scenario, as the success in the development and production of a crop is, in part, linked to the precise distribution of seeds per unit area (Machado; Reynaldo, 2017).

Uniformity in the longitudinal distribution of seeds is essential to guarantee an adequate plant stand and, consequently, good crop productivity (Cortez et al., 2006). Currently, there is a wide variety of seed distribution mechanisms integrated into seeders. Many of these mechanisms are already in commercial use, such as perforated discs (horizontal and vertical), presser fingers, and pneumatic pressure and vacuum systems. Each of these mechanisms has specific characteristics that influence the performance of seeders in terms of uniformity in the longitudinal distribution of seeds (Barr et al., 2019; Rinaldi et al., 2021; Máquina et al., 2022).

In addition to the distributing mechanisms, the appropriate speed of the tractor-seeder set is crucial. Modern seeders do not allow this practice to be carried out with precision above 8 km/h. To guarantee quality sowing, with double spacing and reduced gaps between seeds, attention to sowing equipment is essential. The use of discs with mechanical systems is recommended for speeds between 4 and 6 km/h, while for speeds of up to 8 km/h, it is preferable to use the pneumatic system (Bertelli et al., 2016).

According to Jasper et al. (2011) when comparing mechanical seeders with horizontal discs and pneumatic seeders, the longitudinal distribution of seeds in the pneumatic system is efficient, even at high speeds. As the speed increases, the spacing between the seeds increases and the uniformity decreases, however, the pneumatic system proved to be effective compared to the mechanical system with a horizontal disc. The sowing speed impacts the dosing system, affecting the individualization of the seeds, their passage through the conductive tube, and the speed at which they reach the sowing furrow (Pinheiro Neto et al., 2018; Mudarisov et al., 2020).

Furthermore, as the speed increases, there is a greater opening of the furrow, which influences the variation in seed depth. During the sowing process, the seeds released by the seeder's dosing mechanisms acquire two velocity components: one vertical, due to the free fall of the seed, and the other horizontal, due to the displacement of the tractor-seeder assembly. This horizontal component of speed causes the seeds, when thrown out of their destination location, at the moment of impact with the ground, to change the spacing between them (Barr et al., 2019).

According to Jasper et al. (2011), the distribution of double spacings increased, and acceptable spacings decreased according to sowing speed, always remaining at levels higher than those observed with the horizontal disc seeder system. The horizontal component of the velocity causes the seeds to collide with the wall of the conductive tube, modifying the free fall time from the seed to the ground and, consequently, changing the distance between them (Cortez et al., 2006; Cortez et al., 2020).

The consistency in the deposition of seeds in the furrow, with the presence of the horizontal component, can reduce the damage caused during the movement of seeds through the conductive tube. This helps prevent dents, bends, and cuts that could interfere with the continuous flow of seeds deposited in the furrow (Barr et al., 2019).

Increasing seeding speed has negative effects, such as reducing soil coverage, increasing temperature in the seeding furrow, and decreasing soil moisture. About grain productivity and the mass of one thousand grains, it was observed that the results were superior when co-inoculation was carried out. Furthermore, seeding speeds of up to 4.8 km/h demonstrated greater grain productivity. Increasing sowing speed impairs the uniformity of seed distribution in the furrow, increases temperature, and reduces soil moisture. Co-inoculation of soybean seeds, on the other hand, improves nodulation capacity, nodule mass, grain yield, and thousand-grain mass. Seeding speeds of up to 4.8 km/h provide the best results (Burg, 2021).

3.4. Seeders

Seeders can be categorized according to the seed distribution method and can be precision seeders or continuous flow seeders. Precision seeders are designed to place seeds in the sowing furrow individually, one by one, in rows at regular intervals defined according to the adjusted configuration. On the other hand, continuous flow seeders distribute seeds continuously, which are generally small in size, as they require smaller spacings between them (Abnt, 1996).

The seeder-fertilizer system for direct planting is made up of five essential components: seed distribution, fertilizer distribution, planting depth control, seed compaction, and straw cutting. All of these components must work well to ensure high-quality seeding. Being an integrated system, the failure of one or more of these components can compromise and hinder the establishment of a culture (Mantovani et al., 2015; Hensh; Raheman, 2022).

In some models, seeder fertilizers may include a chassis with a pantographic system, which has two vertical bars, one fixed and the other articulated, in addition to two articulated and parallel horizontal bars. This design allows the seeding unit to operate more easily on uneven terrain, ensuring better uniformity in the positioning of the furrowing mechanisms. This stabilizes the depth of the fertilizer furrows and the positioning of the seeds, as the units move parallel to the soil surface. Thus, the system allows the rows to float, maintaining the adjustments of the rod attack angle and the convergence angle of the double discs (Siqueira, 2018).

According to Balastreire (2014), precision seeders have different types of seed dosing systems, which may include horizontal, inclined, or vertical honeycombed discs, gripping fingers, perforated belts, mugs, or pneumatic vacuum doses. Suction (vacuum) seed dosers are capable of sowing a wide variety of crops and types of seeds, simply by changing the seed discs and adjusting the vacuum pressure.

According to Mialhe (2012), pneumatic vacuum doses operate based on the principle of retaining seeds over an orifice, using the difference in air pressure between rotating surfaces, where seed capture occurs through negative pressure. Portella (2014) explained that the system has a single outlet for the dosed seeds, which are released when the vacuum is neutralized, allowing the seeds to pass through a shutter, after which they are released.

According to Silveira (2016) and Li et al. (2022), pneumatic dosing devices present benefits when distributing seeds accurately, eliminating the need for prior selection of seeds, without causing damage, thus preserving their integrity. Additionally, they can operate at higher speeds and offer greater precision in distributing seeds in the rows, compared to horizontal and inclined disc systems.

However, they have a higher cost, require greater power, and require more detailed adjustment, especially to avoid the formation of seed clusters. To evaluate the uniformity in the longitudinal distribution of precision seeders and seeders-fertilizers, two main parameters are used: the coefficient of variation (CV) of the spacings and the percentage of spacings between seeds in a specific range, divided into a certain number of classes. frequency (Hiroakikuraghi et al., 1989; Shumaev et al., 2020).

3.5. Influence of speed

In a study conducted by Melo et al. (2013), the longitudinal distribution of seeds in corn crops was analyzed using a mechanical and a pneumatic seeder in soil with sub-humid characteristics in Ceará. The operating speeds were 4 and 7 km/h. The results indicated that, for the pneumatic seeder, the coefficient of variation was 50.1% and 53.9% for speeds of 4 and 7 km/h, respectively. Furthermore, it was found that only 64% of the spacings were considered acceptable at the lowest speed, while at the highest speed, this number was 55.4%. The study concluded that the performance of the pneumatic seeder was superior to that of the mechanical seeder and that distribution uniformity was not significantly affected by the speed of travel in the pneumatic system. Additionally, it was observed that soil characteristics exerted a direct influence on the sowing process.

In Mello (2015) study on corn cultivation, the researcher sought to verify the relationship between the placement of fertilizer and seeds, measuring the longitudinal distribution of plants after sowing and at harvest, about four advance speeds during the sowing process (one manual and three carried out by a tractor, at 4.5; 6.0 and 7.5 km h^{-1}), with two seed planting depths (0.05 and 0.10 m). He found results that indicate an interaction between travel speeds and seeding depth for longitudinal distribution. However, the spacing (deficient, double, and ideal) in speeds per tractor at each depth did not show significant differences between them.

Pavan Júnior (2016) in a study focused on soybean cultivation in areas covered by "*mucuna cinza*" and pigeonpea straw, where investigated the impact on soybean development and the performance of a seeder-fertilizer in the direct planting system. The study evaluated three different management methods for cover crops, combined with three travel speeds of the tractor-seeder-fertilizer set, varying between 4.0, 5.0, and 6.0 km/h. During the experiment, one of the variables analyzed was the longitudinal distribution of seedlings, considering normal, faulty, and double spacing. The results indicated that there was no significant difference in the distribution of seedlings to different management methods or movement speeds. However, it was observed that acceptable spacings had an average of more than 50%, while failed spacings were less than 40% and double spacings were less than 10%. This can be attributed to the proximity of the speeds used, as justified.

Jasper et al. (2013) found a statistically significant difference for categories considered acceptable and multiple, however, there was no observation of disparities for spacing classified as failed. The objective of these authors' study was to analyze the impact of sowing speed on soybean production, using horizontal honeycomb and pneumatic configuration seed dosing systems. In the study, seeding speeds ranged between 4, 6, 8, 10, and 12 km h^{-1}, and among the variables examined were the population density of emerged plants and longitudinal distribution.

Mantovani et al. (2015), in their research on the performance of a seeder-fertilizer for the implementation of corn crops with high seeding density, evaluated different aspects, including three-speed levels (5, 7, and 9 km h^{-1}), four types of users (pneumatic, disc, titanium and rampflow) and two spacings between lines (45 and 90 cm). Their conclusions showed that the increase in sowing speed resulted in a greater occurrence of doubles and failures, consequently reducing the percentage of results considered acceptable, regardless of the spacing between rows and the type of meter used.

Bertelli et al. (2016) in their study, investigated the performance of the planting capacity of pneumatic seeders during the introduction of soybean cultivation in the Cerrado of Piauí, Brazil. Two models of seeders were used, and four travel speeds were tested (5.6, 7.0, 8.6, and 10 km h^{-1}). Their conclusions highlighted that both seeders reduced the proportion of spacings considered acceptable as speed increased, in addition to finding that the incidence of double spacing increased with increasing speed, resulting in less uniformity in plant distribution.

4. Conclusion

It was found that higher planting speeds tend to impair emergence uniformity. Seeds planted at higher speeds show significant variations in germination and emergence times, which can be attributed to physical damage to the seeds and reduced precision in soil deposition. This inconsistency in emergence can lead to unequal competition between plants, resulting in heterogeneous development and potentially reducing crop yield.

Furthermore, plant distribution is also negatively impacted by high planting speed; the greater speed results in less precision in the spacing between the seeds, causing agglomeration in some points and large spacings in others. On the other hand, lower planting speeds provide greater emergence uniformity and a more regular distribution of plants. The results verified in this review study suggest that reducing planting speed can be an effective strategy to improve the quality of the soybean stand, contributing to a homogeneous development of the plants and, consequently, to more efficient production and higher yield.

Therefore, it is recommended that soybean producers consider adjusting the planting speed in their operations to achieve emergence uniformity and favorable plant distribution, where implementing this practice can lead to an optimization of resources and a maximization of potential. productivity of soybean crops. Future studies could further explore interactions between planting speed and other agronomic factors, such as soil types, climate conditions, and seed varieties, to further refine management recommendations and practices.

5. Acknowledgement

We would like to thank the Fundação de Amparo à Pesquisa do Estado de Goiás – FAPEG; Financiadora de Estudos e Projetos – FINEP; Fundação Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – CAPES, and Conselho Nacional de Desenvolvimento Científico e Tecnológico – CNPq.

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Funding Information

Not funding.

Author's Contributions

Guilherme Arantes Siega: project structure, data search, article writing, and publication. *Antonio Carlos Pereira de Menezes Filho*: reading, translation, and final evaluation. *Porshia Sharma*: translation, grammar assessment, and final considerations. *Aurélio Ferreira Melo*: final evaluation and submission. *Matheus Vinícius Abadia Ventura*: orientation, final assessment and publication.

Ethics

Not applicable.