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EFFECT OF CONTROLLED TRAFFIC FARMING ON SOYBEAN GRAIN YIELD

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KEYWORDS

Glycine max, precision agriculture, agricultural mechanization.

ABSTRACT

Soybean stands out as one of the most important crops for the Brazilian economy, and adopting techniques to increase yield has become essential. Controlled traffic farming (CTF) can help optimize soybean production and improve crop performance. This study evaluated soybean grain yield in areas with and without implementing controlled agricultural machinery traffic. The experiment was conducted at the Mato Grosso do Sul State University – Cassilândia University Unit (UEMS/UUC) in Cassilândia, Mato Grosso do Sul, Brazil. The trial was arranged in strips and split-plot with six replications. Treatments were applied in areas with and without controlled traffic, combined with different soil cover strategies: *Urochloa* (brachiaria), pearl millet (*Pennisetum glaucum*), a cover crop mix (brachiaria + pearl millet), and spontaneous vegetation. Soybean was sown and cultivated to assess grain yield responses under the different treatments. Vegetative cover with pearl millet and the mixed cover crop led to an increase in yield. Similarly, areas with controlled traffic exhibited the highest grain yield, resulting in a yield gain of 390 kg ha^{-1}. It is concluded that controlled agricultural machinery traffic contributes to higher soybean yields.

INTRODUCTION

Soybean (*Glycine max* (L.) Merr.) is one of the most important crops grown worldwide, as it serves as a major source of vegetable oil for human consumption and industrial applications, as well as a key source of plant-based protein for both human and animal nutrition (Klein & Luna, 2023).

The use of techniques that optimize production is essential, such as controlled traffic farming (CTF), a technology that minimizes soil compaction by using permanent traffic lanes to conduct all field operations (Villa-Henriksen et al., 2021). The cropping area is not disturbed by machinery wheels, which operate exclusively on designated traffic lanes (Hussein et al., 2021). Controlled traffic confines machinery movement to permanent lanes, restricting compaction effects to those specific tracks and allowing for more robust root development in non-trafficked zones (Bulgakov et al., 2022).

In addition to controlled traffic, using soil cover through no-till systems further enhances soil conservation benefits (Godwin et al., 2022). Plant residue (mulch) can help mitigate the impact of machinery wheels on crops (Marques Filho et al., 2022) while also promoting better soybean development (Pereira et al., 2011), by preserving soil moisture and enhancing nutrient cycling (Zhang & Peng, 2021). However, in tropical environments, one of the main challenges is the difficulty of producing and maintaining sufficient mulch on the soil surface due to climatic conditions that accelerate the decomposition of plant residues (Crusciol et al., 2015; Mingotte et al., 2020). Therefore, careful selection of cover crops is essential to ensure effective soil coverage.

Adopting controlled traffic farming with no-till systems presents a viable and sustainable alternative, as it localizes soil compaction and helps improve soil structure, aiming to increase crop yield (Masola et al., 2020). Moreover, precision agriculture techniques and low-impact production models can enhance the environmental efficiency of cropping systems and help mitigate global environmental issues (Medel-Jiménez et al., 2024). Given

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the above, this study aimed to evaluate soybean yield in areas with and without controlled traffic farming associated with different types of soil cover.

MATERIAL AND METHODS

The experiment was conducted at the Mato Grosso do Sul State University – Cassilândia University Unit (UEMS/UUC), located in Cassilândia, Mato Grosso do Sul, Brazil (19°05′50″ S; 51°05′64″ W; altitude 550 meters). The soil in the experimental area was classified as *Neossolo Quartzarênico* (Santos et al., 2018).

The experiment was set up in strips with a split-plot scheme with subplots measuring 4.5 meters in width by 25 meters in length, with six replications. Treatments consisted of the presence or absence of controlled traffic, combined with different soil cover species: spontaneous vegetation, *Urochloa* (brachiaria), pearl millet (*Pennisetum glaucum*), and a mix of pearl millet and brachiaria. Soybean was cultivated to evaluate the effects of controlled traffic and the type of plant residue.

To establish the soil cover treatments, *Urochloa ruziziensis* (brachiaria) was broadcast-seeded at a rate of 10 kg ha^{-1}, while *Pennisetum glaucum* (pearl millet), cultivar BRS 1501, was sown at a rate of 25 kg ha^{-1}. For the mixed treatment (brachiaria + millet), each species was seeded at 50% of its recommended rate. Once the cover crops reached physiological maturity, they were desiccated using glyphosate applied at a spray volume of 200 L ha^{-1}. The application was performed with a tractor-mounted boom sprayer, following the same procedure for the spontaneous vegetation plots.

Following desiccation and with plant residue established for each treatment, soybean was sown during the spring/summer season to assess the effects of controlled traffic. Sowing was carried out mechanically using a five-row planter mounted on the three-point hitch of a 4×2 MFWD tractor with an engine power of 66.19 kW. The soybean cultivar TMG 1180 RR was used, with a seeding rate of 15 seeds per meter, a row spacing of 0.50 m, and an estimated seeding depth of 5 cm.

Along with sowing, planting fertilization was carried out with the application of 100 kg ha^{-1} of single superphosphate. Thirty days after emergence, topdressing fertilization was applied using 50 kg ha^{-1} of potassium chloride across all treatments.

Crop management and phytosanitary practices in the experimental plots followed standard procedures used in commercial farming, including pest and disease monitoring, chemical weed control, and insecticides and fungicides.

When the soybean crop reached maturity 125 days after planting, five plants were randomly collected from each subplot to determine the number of pods and grains through direct counting. Subsequently, all plants within the useful area of the subplot were harvested and threshed. Grain moisture content was measured and corrected to 13% moisture, and grain yield was extrapolated to kilograms per hectare (kg ha^{-1}).

The results were subjected to analysis of variance (ANOVA), and the means were compared using the Tukey test at a 5% probability level. Data analysis was performed using Minitab 16 software.

RESULTS AND DISCUSSION

The number of pods per plant showed a statistically significant difference concerning machinery traffic, with the highest number observed under controlled traffic conditions (Figure 1). However, no significant differences were found among the different soil cover treatments. Controlled traffic farming confines machinery movement to specific lanes, concentrating compaction within these zones and thereby reducing the overall impact on the cultivated area, unlike in systems without controlled traffic (Bulgakov et al., 2022). This may have contributed to improved root development in soybeans under controlled traffic, increasing the number of pods per plant.

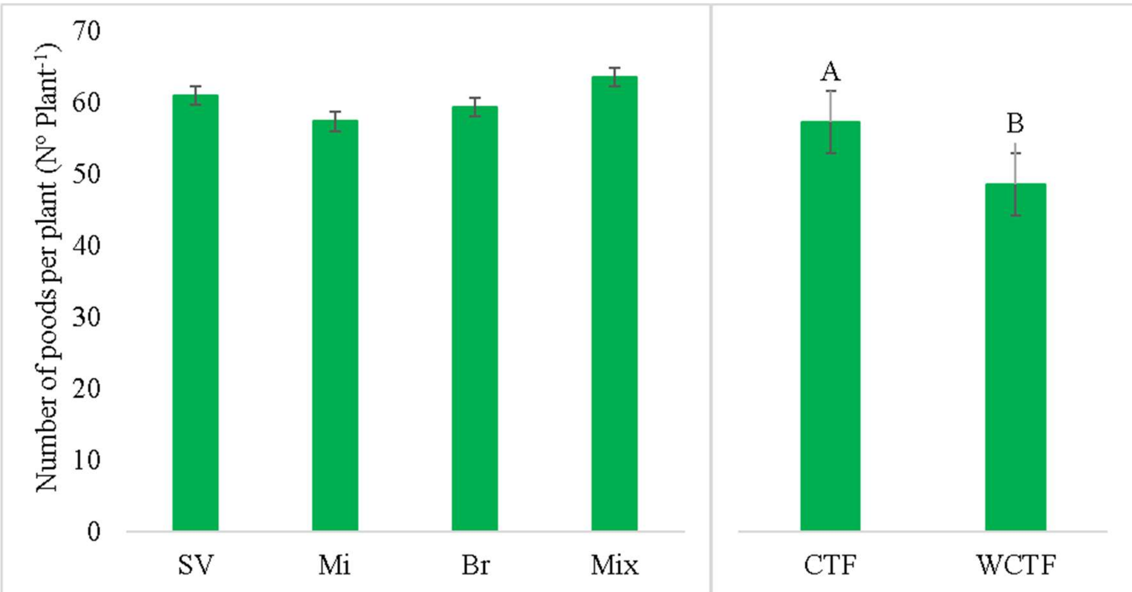

FIGURE 1. Number of pods per soybean plant under different types of soil cover in areas with and without controlled traffic farming. Vertical lines on the bars represent standard deviation. SV - Spontaneous vegetation; Mi – Pearl millet; Br – Brachiaria; Mix – Mix of pearl millet + brachiaria; CTF – With controlled traffic farming; WCTF - Without controlled traffic farming.

The highest number of pods per plant was observed in the treatment with the mixed cover crop (millet + brachiaria), which may be related to an improved soil structure that favors soybean root development. Grasses such as brachiaria and millet have vigorous, aggressive root systems that reach deep into the soil, enhancing soil conditions. These characteristics improve the rhizosphere environment when such species are included in crop rotation systems, benefiting soil properties and the performance of succeeding crops like soybeans (Azevedo et al., 2021; Ferreira et al., 2021).

Figure 2 presents the results for the number of grains per soybean plant. No statistically significant differences were observed for soil cover type or machinery traffic. However, the mixed cover crop treatment resulted in more grains than the other treatments. Similarly, although the difference was not statistically significant, areas under controlled traffic had more grains per plant than those without controlled traffic, 135 and 119 grains per plant, respectively.

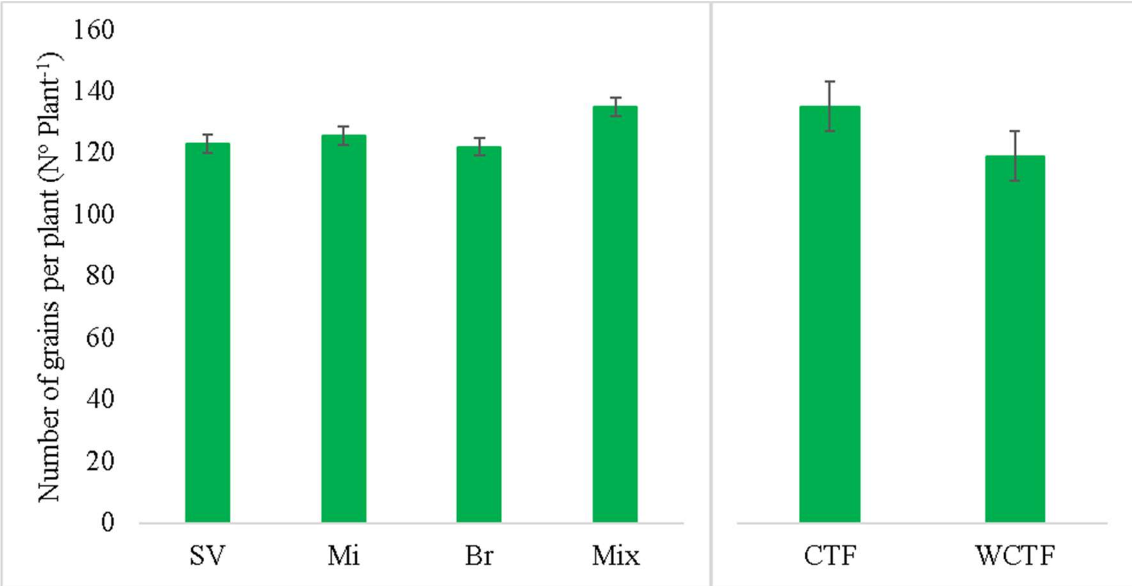

FIGURE 2. Number of grains per soybean plant under different types of soil cover in areas with and without controlled traffic farming. Vertical lines on the bars represent standard deviation. SV - Spontaneous vegetation; Mi – Pearl millet; Br – Brachiaria; Mix – Mix of pearl millet + brachiaria; CTF – With controlled traffic farming; WCTF - Without controlled traffic farming.

Greater crop diversity within the production system can help improve soil physical quality in compacted environments, mitigating crop development and yield reductions and contributing to soil structure recovery (Ferreira et al., 2023). For example, using a mixed cover crop combined with controlled traffic farming can support better crop development. In contrast, increased levels of random traffic can negatively affect root growth, above-ground biomass, and overall crop development and yield (Sivarajan et al., 2018).

Soybean yield did not show statistically significant differences for either the type of soil cover or the type of machinery traffic (Figure 3). However, treatments with pearl millet and the mixed cover (millet + brachiaria) resulted in yield increases of 3,614 and 3,376 kg ha^{-1}, respectively. This improvement can likely be attributed to the greater amount of residual plant material (mulch) left on the soil surface, which may have helped buffer the soybean crop against environmental stresses.

Ferreira et al. (2021) also reported that millet mulch improved soybean yield, as its thicker layer of dry matter provided better soil conditioning. Additionally, millet has a highly aggressive root system capable of reaching significant soil depths, enhancing the rhizosphere environment when included in crop rotation systems. This benefits soil properties and the yield of succeeding crops (De Assis et al., 2017; Azevedo et al., 2021).

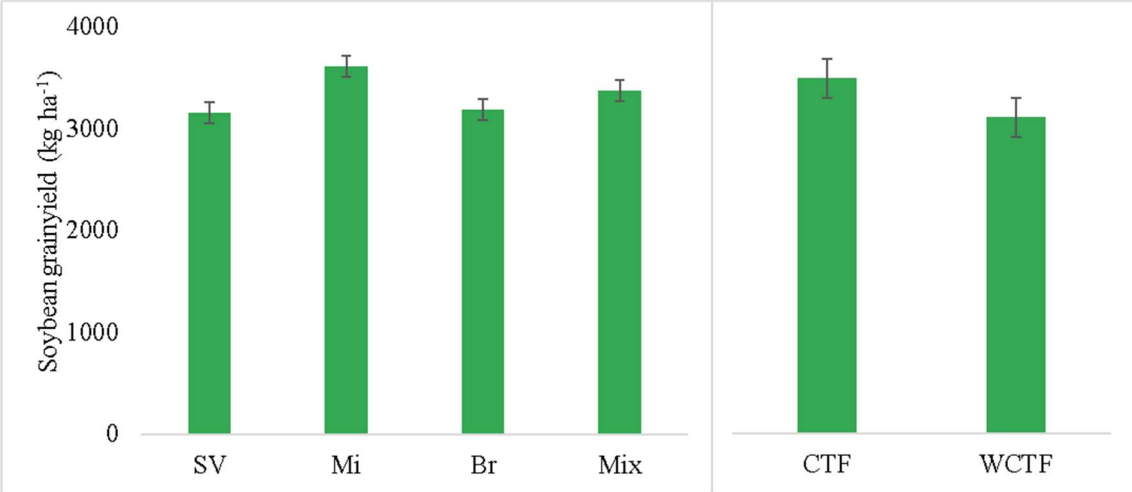

FIGURE 3. Soybean grain yield under different types of soil cover in areas with and without controlled traffic farming. Vertical lines on the bars represent standard deviation. SV - Spontaneous vegetation; Mi – Pearl millet; Br – Brachiaria; Mix – Mix of pearl millet + brachiaria; CTF – With controlled traffic farming; WCTF - Without controlled traffic farming.

According to Chioderoli et al. (2012), soil cover with brachiaria residues can increase soybean grain production. Godwin et al. (2022) concluded that conservation tillage systems that maintain soil cover have a long-term positive effect on crop yield and reduce the establishment costs of cropping systems.

In areas under controlled traffic, higher soybean yield was observed (3,529 kg ha^{-1}) compared to areas without controlled traffic (3,139 kg ha^{-1}), resulting in a grain yield increase of 390 kg ha^{-1} (Figure 3). By using controlled traffic and designating compacted lanes, areas without machinery traffic provide a more favorable environment for root development, ultimately enhancing grain yield compared to systems with random machinery movement. This grain yield gain may be attributed to reduced compaction between the traffic lanes due to lower traffic intensity, likely allowing for improved root growth (Botta et al., 2022). However, Girardello et al. (2017) found no differences in soybean yield under controlled traffic with varying intensities, and similarly, Sivarajan et al. (2018) reported that compaction within traffic lanes did not affect soybean yield.

CONCLUSIONS

Adopting controlled traffic farming proved to be a viable option for optimizing soybean grain yield, as the concentration of traffic lanes results in larger areas free from machinery passage. This, in turn, contributes to improved crop development and yield.

Soil cover contributed to increased soybean yield, particularly using the mixed cover crop, which provided a greater amount of residual plant material for the succeeding crop and supported improved development and yield.

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