SOYBEAN YIELD EVALUATION UNDER DIFFERENT SOIL COVER MANAGEMENT IN NORTHWESTERN RIO GRANDE DO SUL

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ABSTRACT: This study aimed to evaluate the effects of different soil management systems on soybean yield and soil quality indicators in a dystrophic Red Latosol in the municipality of Tiradentes do Sul, RS, Brazil. Two areas under no-tillage system were compared: one with crop rotation and cover crops (corn, radish, wheat, and a mix of cover species), and another conducted under the traditional soybean-wheat system with winter fallow. Soil physical and chemical variables, grain yield, and weed occurrence were analyzed. The results indicated that the use of cover crops improved soil pH, increased dry matter and organic matter input, and resulted in a 1,320 kg ha^{-1} increase in soybean productivity. It is concluded that the use of cover crops and crop diversification is more efficient for soil conservation and increasing soybean yield.

Keywords: crop rotation; soil quality; Latosol; soil conservation; *Glycine max*.

AVALIAÇÃO DA PRODUTIVIDADE DA SOJA EM DIFERENTES MANEJOS DE COBERTURA DO SOLO NO NOROESTE DO RIO GRANDE DO SUL

RESUMO: Este trabalho objetivou avaliar os efeitos de diferentes manejos do solo sobre a produtividade da soja e indicadores de qualidade edáfica, em um Latossolo Vermelho distrófico no município de Tiradentes do Sul – RS. Foram comparadas duas áreas cultivadas sob sistema de plantio direto: uma com rotação de culturas e cobertura vegetal (milho, nabo, trigo e mix de plantas de cobertura), e outra conduzida sob o modelo tradicional soja-trigo e pousio invernal. Foram analisadas variáveis físico-químicas do solo, produtividade de grãos e ocorrência de plantas daninhas. Os resultados indicaram que o uso de plantas de cobertura promoveu melhorias no pH, maior aporte de matéria seca e orgânica ao solo, e incremento de 1.320 kg ha^{-1} na produtividade da soja. Conclui-se que o manejo com cobertura vegetal e diversificação de culturas é mais eficiente na conservação do solo e no aumento da produtividade da soja.

Palavras-chave: Rotação de culturas; Qualidade do solo; Latossolo; Conservação do solo; *Glycine max.*

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INTRODUCTION

Soybean (*Glycine max*) holds a prominent position in Brazilian agriculture, particularly in the state of Rio Grande do Sul, being one of the main economic crops in the northwestern region (CONAB, 2024). With the expansion of agribusiness, concerns regarding the sustainability of production systems have also increased, especially in relation to soil and water conservation (GONTIJO et al., 2022).

Cover crops are plant species cultivated primarily to protect and enhance the physical, chemical, and biological properties of the soil, especially during fallow periods between main crops. They are not necessarily intended for harvest but rather for providing ecosystem services such as erosion control, nutrient cycling, organic matter accumulation, weed suppression, and improvement of soil structure. Grasses, legumes, and brassicas are widely used for this purpose, either individually or in species mixtures.

Long-term use of cover crops is considered one of the foundational pillars of conservation tillage systems, such as no-tillage (Calegari et al., 2022). One of the main benefits of using cover crops is the protection of soil against both water and wind erosion. Vegetative cover functions as a physical barrier, reducing the impact of raindrops, enhancing water infiltration into the soil, and decreasing surface runoff. Additionally, the root systems of cover crops contribute to the formation of soil aggregates, increasing resistance to erosion (PIMENTEL et al., 2005). Several studies have shown that the use of cover crops significantly reduces soil loss by erosion when compared to bare soil systems (LOPES et al., 2012; Blanco-Canqui et al., 2015; Dabney et al., 2001).

The adoption of conservation practices, such as the no-tillage system combined with the use of cover crops, has proven effective in mitigating soil degradation issues, including erosion and surface compaction (Calegari et al., 2022; Derpsch et al., 2010). Winter fallow, a practice traditionally employed in the “Celeiro” region of Rio Grande do Sul (RS), consists of leaving the soil uncultivated during the winter period, aiming to control weeds and restore soil fertility. However, this practice may result in organic matter loss, increased soil erosion, and enhanced potential for compaction (SILVA et al., 2015).

As an alternative to winter fallow, the use of cover crops has shown promise by providing several benefits to the production system, such as increasing organic matter content, improving soil structure, and reducing erosion (BOENI et al., 2021). Red Latosols, which predominate in the study region, are characterized by high acidity, low natural fertility, and a clayey texture, requiring careful management. Their physical and chemical structure can be improved through the addition of plant biomass and crop diversification, strategies that enhance aggregate stability and promote root system development (BORTOLUZZI et al., 2008; CASTRO et al., 2011). Studies conducted in southern Brazil have shown that the adoption of cover crops during the off-season significantly improves soil fertility and the nutrient status of subsequent soybean crops (Rosa et al., 2020). Andrade et al. (2025) also reported increases in soil organic matter content, microbial activity, and crop productivity in systems using legumes and grasses as cover species. These findings are supported by experiments demonstrating that biodiversity through the use of these species contributes to soil health, enhances soybean yield, and increases the resilience of agricultural systems (Tessaro et al., 2019; Lima et al., 2017).

In addition, the integration of cover crops into crop succession has proven effective in weed control, nutrient cycling, and compaction reduction. Araújo et al. (2019) observed that the use of black oat, forage radish, and mixed cover crop species significantly reduced weed infestation and promoted surface residue accumulation an essential factor for water infiltration and soil moisture conservation (Oliveira et al., 2020; Tessaro et al., 2019). Another notable potential of cover crops lies in their ability to improve the physical, chemical, and biological quality of the soil, thereby increasing grain crop yields, such as soybean. The incorporation of cover crop biomass into the soil enhances organic matter content, improves soil structure, and fosters the development of a more active microbial community, all of which contribute to improved soil fertility (Lima et al., 2017).

Thus, this study aimed to evaluate the impact of different soil management systems, with and without the use of cover crops on soybean productivity and the quality of a dystrophic Red Latosol under the climatic conditions of the northwestern region of Rio Grande do Sul.

MATERIALS AND METHODS

The study was conducted between October 2023 and May 2024 in the municipality of Tiradentes do Sul, located in the northwestern region of the state of Rio Grande do Sul, Brazil. The area has a humid subtropical climate, classified as Cfa according to Köppen, with well-distributed rainfall throughout the year. The predominant soil in the region is classified as dystrophic Red Latosol, with a clayey texture, low natural fertility, and high susceptibility to erosion. According to EMATER-RS/ASCAR (unofficial data), the rainfall recorded during the experimental period was within the expected range, as shown in Figure 1.

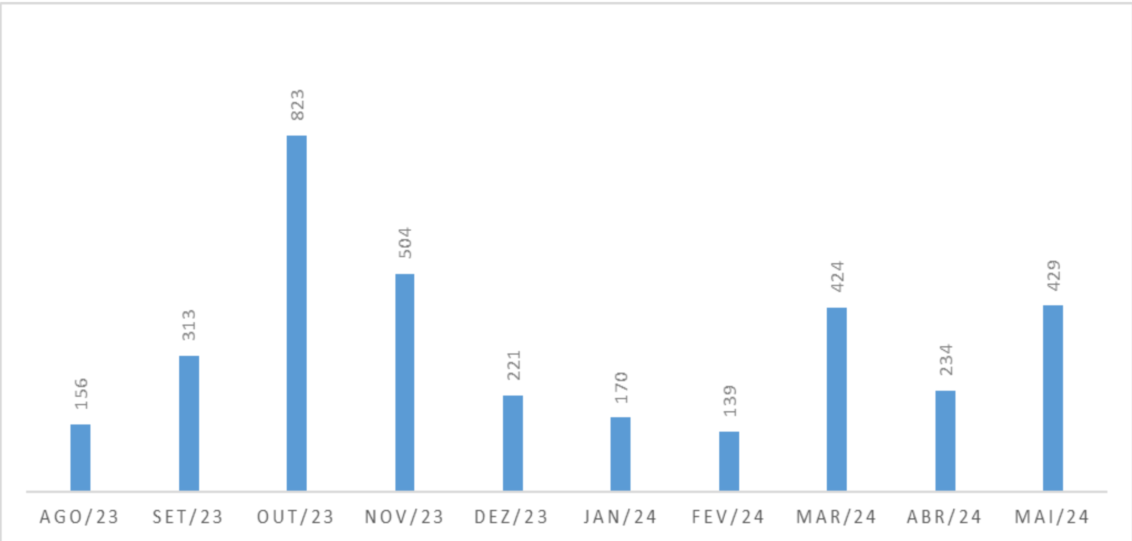

Figure 01 – Historical precipitation data (mm) recorded in the region during the 2023/2024 soybean growing season. Source: EMATER ASCAR – Tiradentes do Sul – RS (2024).

The experimental area consisted of two adjacent plots located on different farms, both with a similar management history over the past five years regarding the main crop (soybean), no-tillage system, and fertilizer use. The plots were designated as Area 01 and Area 02, as shown in Figure 2. Area 01 is managed under a soybean-wheat succession system, with fallow at the end of summer. This plot showed signs of degradation, such as water erosion rills, absence of contour terraces, and low vegetative cover during the off-season. Area 02 follows a crop rotation system including soybean, corn, and wheat, along with the regular use of cover crops during the off-season.

Figure 2 – Experimental areas located in the municipality of Tiradentes do Sul, where the study was conducted. Source: Google Earth (2024).

No formal experimental design was applied; instead, assessments were conducted through direct comparison between the two soil management systems, without statistical replication. An observational model was adopted based on commercial farming practices traditionally used in the region.

Both areas were sown on the same date, using the same soybean cultivar, and followed the recommended management practices and cultural treatments established by official agencies for the region throughout the cropping cycle (EMATER/RS-ASCAR, 2023). Soybean yield was determined through random and localized sampling within the plots at the time of harvest for the 2023/2024 season. The sampled data were converted to yield in kilograms per hectare (kg ha^{-1}).

Soil cover in Area 02 consisted of a commercial seed mix from the company Raix, containing the following species: forage pea, black oat, forage radish IPR 116, and wild radish (*Raphanus raphanistrum*). This mixture was sown prior to both corn and wheat crops, ensuring year-round soil coverage throughout the agricultural cycle. In Area 01, no cover crops were used, and the field was left fallow after soybean harvest until wheat sowing.

Both areas received fertilization based on soil chemical analysis results obtained in September 2023. Area 01 received 150 kg ha^{-1} of potassium chloride and 300 kg ha^{-1} of an NPK 03-21-21 fertilizer blend at sowing. Area 02 received only maintenance fertilization using the same NPK formulation.

Soil chemical analyses were performed after soybean harvest in May 2024. Samples were collected using a cutting spade at depths of 0-10 cm and 10-20 cm, following the methodology established by Embrapa (1997). The evaluated parameters included phosphorus

(P), potassium (K), organic matter (OM), pH in water, SMP index, and exchangeable aluminum (Al). Interpretation of the results followed the criteria established in the Fertilization and Liming Manual for the States of RS and SC (CQFS RS/SC, 2016).

No statistical analysis was conducted due to the absence of an experimental design with replicates. Comparisons between management systems were made descriptively, based on laboratory results, field observations, and soybean crop yield.

RESULTS AND DISCUSSION

Soil chemical analysis revealed significant differences between the management systems of the two evaluated areas (Table 1). Although phosphorus levels were similar in both plots (3.0 mg dm^{-3}), Area 01 presented higher potassium concentrations (181 and 171 mg dm^{-3} in the 0-10 cm and 10-20 cm layers, respectively), which may be attributed to the application of potassium chloride as a corrective measure prior to soybean sowing. In contrast, Area 02, managed with cover crops and crop rotation, showed better results for pH and SMP index, indicating greater chemical stability and a reduced need for liming.

Table 1 – Soil chemical analysis results from the evaluated areas.

Soil layer (cm)	P (mg/dm³)	K (mg/dm³)	OM (%)	pH (H_2O)	SMP	Al (cmolc/dm³)
Area 01						
0-10	3,0	181	3,1	5,1	5,4	0,2
10-20	3,0	171	2,9	5,2	5,4	0,0
Area 02						
0-10	3,0	103	3,0	5,2	5,6	0,2
10-20	3,0	80	2,8	5,4	5,5	0,0

Despite lower potassium fertilization, Area 02 presented higher pH values and lower aluminum saturation, which may be related to increased biological activity and the accumulation of organic residues promoted by cover crops. According to Castro et al. (2011), the continuous addition of plant biomass contributes to pH buffering and improves the soil's cation exchange capacity.

Organic matter content was slightly higher in Area 01 in the surface layer; however, this difference may be associated with the timing of sampling, as the biomass in Area 02 had not yet fully decomposed. Boeni et al. (2021) emphasize that the presence of straw from mixed grasses and legumes promotes the gradual increase of organic matter, which becomes more evident over continuous management cycles.

Torres et al. (2006) studied thermal amplitude and gravimetric soil moisture under different cover crop residues and found that grasses are more resilient and better adapted species, with pearl millet showing the best performance. Lara (2021) reported in her experiment that black oat and ryegrass cover helped mitigate drought effects on soybean yield. Moreover, soybean grown after corn showed increased grain production (Muzilli, 1981).

Soybean productivity was considerably higher in Area 02, with an increase of 1,320 kg ha^{-1} compared to Area 01 (Figure 3). This result reinforces the importance of soil cover and the diversity of root systems provided by crop rotation. According to Lara (2021), soybean-corn systems with reduced straw cover can negatively affect soil physical attributes such as infiltration and water retention, directly impacting crop development. Cruz et al. (2021) state that the soybean–corn rotation system is essential for disease control and increased grain yield in soybean crops.

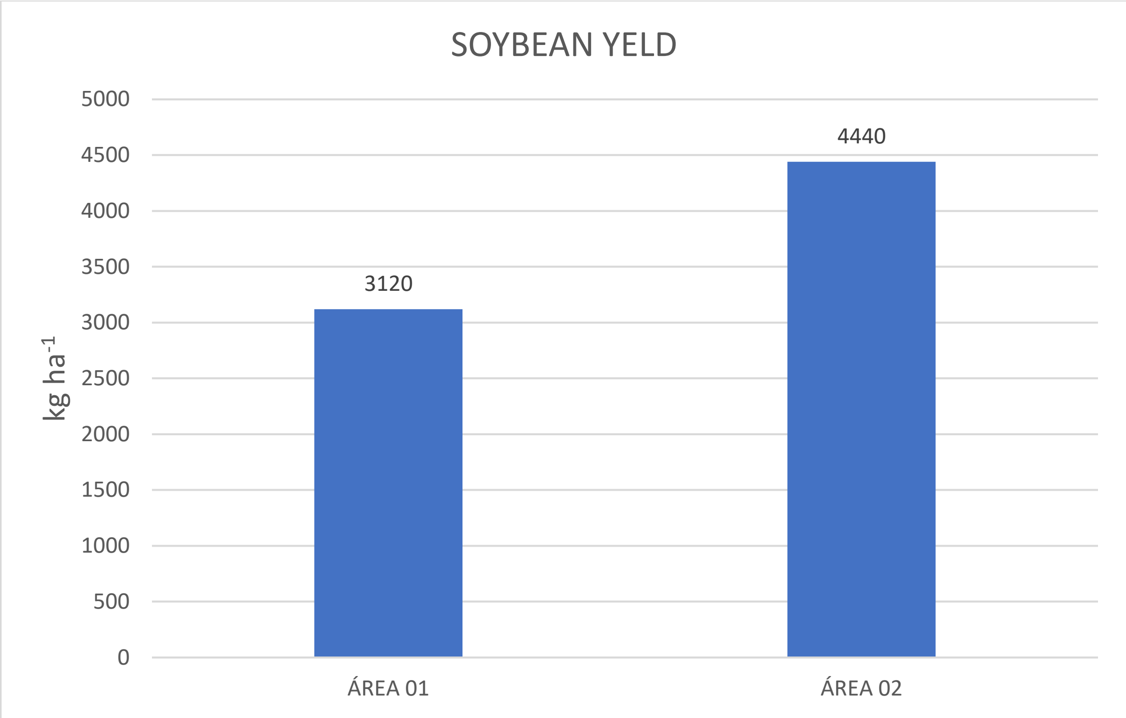

Figure 3 – Soybean yield during the 2023/2024 growing season in the two study areas.

Considering the average soybean price in the northwestern region of Rio Grande do Sul, which was approximately R$ 121.00 per 60-kg bag (CONAB, 2024), this represents an additional income of R$ 2,662.00 per hectare for the producer when adopting the cover crop management system (Area 02). The introduction of a species mix helps reduce weed pressure by maintaining soil cover, particularly when implemented before corn in the corn-soybean rotation system. In contrast, Area 01, managed under a soybean-wheat succession with fallow during late summer and early autumn, showed a wide variety of emerging weed species, resulting in increased costs for chemical control (Figure 4).

Vegetative cover also contributed to reduced weed infestation in Area 02, lowering herbicide application expenses. In Area 01, however, heavy infestation was observed after the fallow period, with the predominance of hard-to-control species such as horseweed (*Conyza* spp.) and sourgrass (*Digitaria insularis*), as illustrated in Figure 4. Studies by Araújo et al. (2019) show that soil cover acts as a physical barrier to weed emergence and supports integrated weed management.

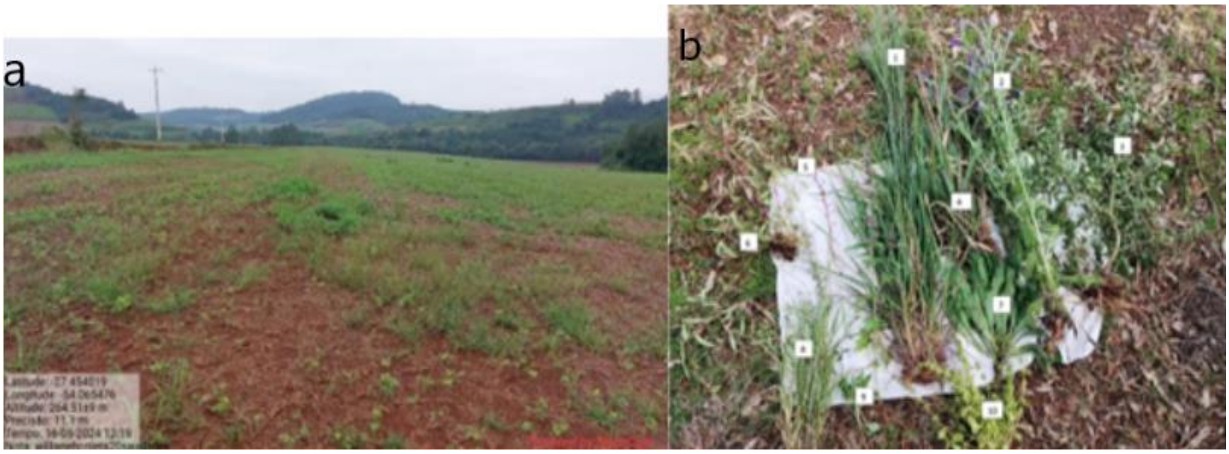

Figure 4 – Presence of weed species in Area 01 (a) and soil cover in Area 02 (b).

Additionally, during the soybean growing season, rainfall exceeded historical averages, particularly in October 2023, when accumulated precipitation surpassed 800 mm. This condition contributed to intensified erosion processes in Area 01, where the absence of straw left the soil exposed to disaggregation and surface runoff. In contrast, in Area 02 (Figure 5), the cover provided by the species mix acted as a mechanical barrier, cushioning the impact of raindrops and promoting water infiltration into the soil (Heckler et al., 1998).

Cover crop mixtures proved effective under no-tillage systems, contributing to increased productivity of the main crop (soybean). Araújo et al. (2019) reported that cultivating cover crops during the off-season with known growth cycles and phenological traits facilitates their mechanical or chemical termination prior to sowing the main summer crop. Furthermore, in areas where corn rotation is practiced, there is a higher input of crop residue and longer surface persistence of this straw, which protects the soil due to its slower decomposition rate.

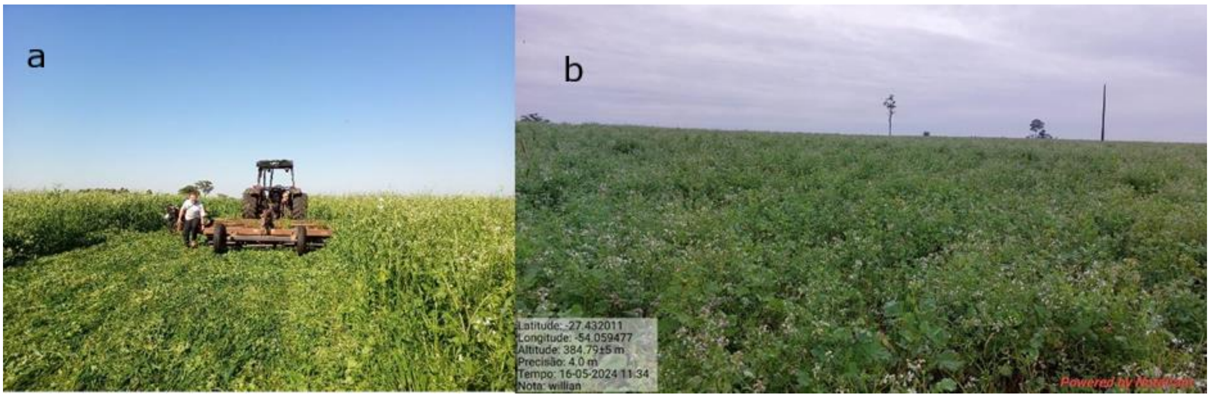

Figure 5 – Cover crop mix preceding the corn crop in the 2021/2022 season (a); cover crop mix preceding the wheat crop in the 2022/2023 season (b).

These findings are in agreement with recent studies that identify the use of cover crops as a key strategy for increasing the resilience of agricultural systems to climatic variability, thus contributing to the productive stability of soybean (Andrade et al., 2025; Oliveira et al., 2020).

FINAL CONSIDERATIONS

The adoption of conservation practices in soil management, such as crop rotation and the use of cover crops, showed positive results in improving soil quality and increasing soybean productivity. Area 02, managed under these practices, exhibited higher biomass production, improved water retention capacity, and greater organic matter conservation factors that directly contributed to increased yield.

Maintaining soil cover throughout the year also contributed to reduced erosion, improved soil structure, and greater crop resilience under water stress conditions such as dry spells and prolonged droughts, which are increasingly frequent in southern Brazil.

In addition to its role in drought years, soil cover also proved to be essential under conditions of excessive rainfall. In October 2023, the initial period of the experiment, more than 800 mm of rain were recorded, creating a critical scenario of water excess. Under these conditions, the presence of straw and living cover provided by the cover crops helped protect the soil against runoff, contain erosion, and reduce losses of soil and nutrients from the fields. Thus, vegetative cover not only helps stabilize productivity in dry years but also acts as a physical barrier during extreme rainfall events, promoting soil conservation and the sustainability of the production system.

Beyond agronomic and environmental benefits, the increase in productivity allows for higher gross income, which can offset the investments required for sustainable practices. Improvements in soil health, along with more efficient water use, reduce dependence on external inputs, thereby enhancing both the economic and environmental sustainability of the production system.

Finally, it is recommended that each farm adapt and expand the use of conservation techniques according to its specific edaphoclimatic conditions, focusing on maintaining soil fertility, ensuring sustainability, and maximizing productivity over time.

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