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# ANTICIPATION OF FERTILIZATION IN WHEAT ON SOYBEAN PRODUCTIVITY: CASE STUDY IN PASSA SETE – RS

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## ABSTRACT
The objective of this study was to evaluate soybean productivity under the anticipation of chemical fertilization in wheat crops. The experiment was carried out during the 2023/2024 agricultural year, in the municipality of Passa Sete - RS. The design used was completely randomized with 7 treatments in 4 replicates. The treatments used were: T1: control; T2: 100% of total wheat fertilization; T3: 100% of total soybean fertilization; T4: 25% of total wheat fertilization + 75% of total soybean fertilization; T5: 75% of total wheat fertilization + 25% of total soybean fertilization; T6: 100% of total wheat fertilization + 100% of total soybean fertilization and T7: 50% of total wheat fertilization + 50% of total soybean fertilization. The NPK formula used for fertilization was 05-20-20 in both crops. Final productivity and hectoliter weight were evaluated in the wheat crop. In the soybean crop, the variables evaluated were: degree of lodging, plant height, number of pods, number of grains per pod, number of branches, thousand-grain weight, and final productivity. With the data obtained, analysis of variance and Tukey test were performed, with a 95% significance level. The use of the total fertilizer recommendation for wheat and soybean before wheat sowing promoted a greater increase in wheat productivity and better quality in hectoliter weight for industrial marketing. The anticipation of chemical fertilization of soybeans in the wheat crop interfered positively with the number of branches, productivity, and thousand-grain weight in the soybean crop.

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## INTRODUCTION

Grain production in Brazil is certainly one of the country's greatest strengths, with soybeans, corn, rice, and wheat being some of the most widespread crops in the South American country. Wheat (Triticum aestivum L.) is one of the three most cultivated cereals in the world. In the 2023/2024 harvest, Brazil cultivated approximately 3.08 million hectares of wheat, reaching an average productivity of 2,942 kg ha-1 (Conab, 2024). Wheat cultivation in Brazil is mainly a winter crop, and 80% of the total volume produced is concentrated in the states of Paraná and Rio Grande do Sul (Landau et al., 2020).

Similarly, soybeans (Glycine max L.), are a crop of high economic significance and Brazil's main agricultural commodity, with production spread across almost all states. The world's largest soybean producers are Brazil, the United States, Argentina, China, India, and Paraguay (USDA, 2023). In the 2022/2023 harvest, Rio Grande do Sul (RS) ranked fourth in soybean production (Conab, 2024).

Both crops are part of the agricultural cycle of many properties in the state. Hirakuri et al. (2014) highlight that soybeans are not only the most-produced grain in Brazil, widely traded both domestically and internationally. They also involve one of the largest grain-related industrial complexes in the country, made up of numerous companies from small to transnational corporations and with a higher consumption of seeds, fertilizers, and pesticides.

Despite the large scale of production, soybean cultivation in Brazil is environmentally conscious. This is achieved through sustainable agricultural practices initiated under this crop; for example, the crop-livestock integration system and various planting techniques are used. These innovative land use systems allow for the intensive use of land with low environmental impact, which helps to reduce the pressure to open new areas, thus contributing to the preservation of the environment (Holloway, 2004).

Wheat is usually grown in the winter, before soybean crops, with the aim of crop rotation in a direct planting system and an alternative for economic gain. With the introduction of this planting system (wheat-soybean), it is now possible to bring forward fertilization, whether with a specific nutrient or to fully fertilize the summer crop under the winter crop, i.e., to apply part of the chemical fertilizer required by soybeans at the same time as the wheat is sown.

This operation aims to improve logistics and make better use of the nutrients applied in the system. In addition, using fertilizer in advance can allow the producer to predict the management of the next crop, optimizing operations such as sowing and nutrient availability.

Another advantage that can be mentioned with early fertilization about the previous harvest is the formation of straw or cover for direct sowing, generating a greater increase in the production of organic matter for the agroecosystem, promoting soil protection, moisture retention, reduction of thermal amplitude in the soil and nutrient cycling. Subsequently, the nutrients will be gradually converted into forms available for summer crops through the mineralization of organic matter.

Wheat and soybeans, like all crops, require a nutritional contribution consisting of macro and micronutrients. Among the macronutrients provided at the base and as the top dressing of the crop, nitrogen, phosphorus, potassium, calcium, and magnesium stand out, these being the most extracted during the Poaceae cycle (De Bona et al., 2016).

System fertilization is a new approach to fertilizer application. Its main objective is to ensure high efficiency in the use of nutrients (Júnior et al., 2010). The description involves the strategic replacement of nutrients based on information from established soil fertility situations, with knowledge of the nutrient flows that enter and leave the system (Carvalho et al., 2021).

Therefore, to increase the productivity of the plants involved in the system, adequate fertilization management becomes important. Proper fertilization should consider factors such as soil and plant characteristics, climate, and type of management. Among the methods that can be used are crop rotation and succession, which makes it more efficient in preventing pests due to the accumulation of substances, causing them to feed on the same species in successive harvests. In addition, some manuals suggest the addition of nutrients – such as potassium – even when they are already present in large quantities in the soil.

When deciding on fertilization recommendations, the amount of nutrients exported is usually taken into account; however, the amount of nutrients recycled through the decomposition of straw deposited in the soil is almost always ignored. Therefore, little attention is given to the practical aspects of continuous nutrient cycling as a broader scenario, so that it is then possible to perform these activities more rationally: (Assmann et al, 2017).

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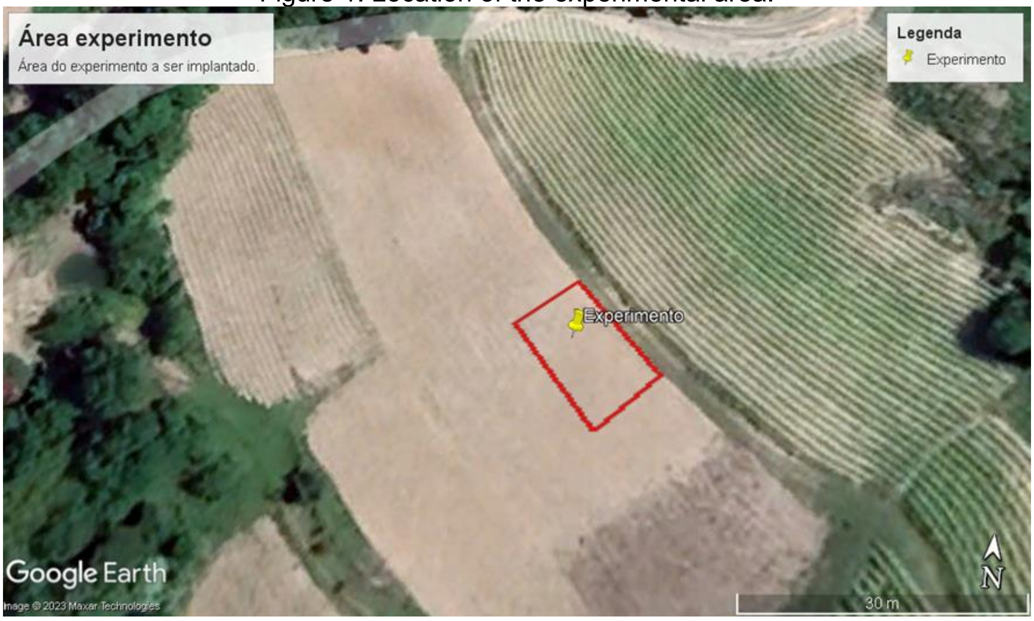
Zhang (2017) suggests that fertilization during the winter provides more favorable weather conditions for the use of nutrients, leading to a decrease in nitrogen losses to the atmosphere. In addition, the use of fertilization systems helps to mitigate the negative effects of saline stress caused by potassium fertilizers applied directly to the sowing furrow. This reduces water stress and potassium leaching, preventing nutrient losses (Ernani et al., 2007).

Given the above, the anticipation of fertilization aims to make better use of nutrients and improve planting logistics. Thus, the study was developed to evaluate soybean productivity under the anticipation of chemical fertilization in wheat crops.

## METHODOLOGY

The study was carried out with wheat and soybean crops during the 2023/2024 agricultural year, in a producer's area in the municipality of Passa Sete - RS, located at 29°31'53.09"S Latitude and 52°57'28.03"W Longitude at an altitude of 469 meters. The experiment took place in an area of 224 m² where corn had previously been planted (Figure 1).

Figure 1. Location of the experimental area.




SOURCE: AUTHORS

**Soil analysis** (Table 1) was collected about three months before sowing the winter crop. The goal was to correct the soil and calculate the fertilization for the crops to be planted. The soil was corrected with limestone before wheat cultivation.

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**Table 1. Chemical analysis of the soil in the experiment.**

| Chemical Attribute | Unit | Soil |
|---|---|---|
| SMP | | 5.3 |
| pH (H2O) | | 5.0 |
| Organic Matter (OM) | % | 1.4 |
| Cation Exchange Capacity (CEC) | mmol kg-1 | 10.67 |
| Clay | % | 27 |
| Aluminum (Al3+) | comic dm-3 | 0.9 |
| Calcium (Ca2+) | comic dm-3 | 2.7 |
| Magnesium (Mg2+) | cmolc dm-3 | 1.0 |
| Potassium (K+) | mg dm-3 | 107.00 |
| Base Saturation (V) | % | 37.23 |
| Phosphorus (P) | mg dm-3 | 45.3 |
| Organic Carbon (OC) | g kg-1 | 23 |

Source: Author.

The experimental design used was a completely randomized design with 7 treatments and 4 replications. Each plot measured 4 meters in length and 2 meters in width, totaling 8 m² for wheat and soybean in succession. The plot area used for data collection represented a 1 m² central area in the wheat plot and 3 central rows of soybeans with 4 linear meters.

The fertilization source used in the experiment was the NPK 05-20-20 formula (source of nitrogen, phosphorus, and potassium), except for treatment 1, the control, with no fertilization. Fertilization, when applied, was calculated based on the soil analysis (Table 1) and applied broadcast on the experimental area before sowing, by the treatments in Table 2.

In treatments 2 and 3, the total fertilization was calculated and applied separately for each crop, with 100% of the total fertilization for wheat and 100% of the total fertilization for soybeans, respectively. In treatments 4, 5, and 7, the total fertilization recommended for each crop varied: T4 = 25% of the total fertilization for wheat + 75% for soybeans; T5 = 75% for wheat + 25% for soybeans; T7 = 50% for wheat + 50% for soybeans. The application of the treatments occurred before sowing wheat and before sowing soybeans. Treatment T6 involved the application of 100% of the total fertilization for both wheat and soybeans before sowing wheat.

For the wheat crop, except for the control, two cover fertilizations with urea (40-00-00) were carried out at the phenological stages V3 and V7. A dose of nitrogen fertilizer of 273 kg ha-1 was applied as a top dressing, with 60% of the total dose at V3 and the remaining 40% at V7.

**Table 2. List of treatments used in the experiment.**

| Treatments | Description | NPK Wheat Quantity (kg ha-1) | NPK Soybean Quantity (kg ha-1) |
|---|---|---|---|
| T1 | Control | 0 | 0 |
| T2 | 100% total wheat fertilization | 200 | 0 |
| T3 | 100% total soybean fertilization | 0 | 250 |
| T4 | 25% wheat + 75% soybean total fertilization | 112.5 | 337.5 |
| T5 | 75% wheat + 25% soybean total fertilization | 337.5 | 112.5 |
| T6 | 100% total fertilization for wheat and soybean | 450 | 0 |
| T7 | 50% wheat + 50% soybean total fertilization | 225 | 225 |

Source: Author.

For wheat sowing, the variety used was TBIO AUDAX, sown at a density of 120 kg ha-1. The winter crop was manually sown broadcast on 06/24/2023 and harvested on 11/25/2023. In terms of phytosanitary management, which involves controlling weeds, pests, and diseases, it was carried out based on technical recommendations normally prescribed for wheat cultivation.

Soybean sowing occurred on 12/06/2023, using the NEO 610 IPRO cultivar, with a 3-row seeder spaced 0.5 m between rows, 3 cm deep, and approximately 13 seeds per linear meter. In terms of phytosanitary management, it was done according to the technical recommendations typically prescribed for soybean cultivation, and the harvest occurred on 04/21/2024.

The following variables were evaluated for wheat: productivity and hectoliter weight. To estimate these variables, a manual harvest of each plot was conducted, and then a grain thresher was used to thresh each treatment. The moisture content was corrected and standardized to 13%.

For the soybean crop, the following variables were evaluated: plant height, number of pods, number of grains per pod, lodging degree, number of branches, thousand-grain weight, and productivity. The lodging degree was assessed using the methodology described by Segatelli (2004), employing a scale with visual ratings from 1 to 5, where:

- 1 = 0-20% lodging,
- 2 = 21-40% lodging,
- 3 = 41-60% lodging,
- 4 = 61-80% lodging,

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- 5 = 81-100% lodging. Plant height was measured using a tape measure, recording 5 plants in the central row of each plot, and then the average for each treatment was calculated.

For the results of the number of branches, number of pods, number of grains, and grains per pod, 5 plants from the central row of each plot were collected. Final productivity and thousand-grain weight were obtained from harvesting the usable area of each plot, which was 6 m². The grains for each treatment were then threshed using a grain thresher to assist in the process. The final moisture content was standardized at 13%.

All collected variables were subjected to a normality test of errors, and subsequent analysis of variance was conducted. In cases of disparity between treatments, the Tukey test at 5% probability was used.

## RESULTS AND DISCUSSION

Table 3 presents the average values for wheat productivity and hectoliter weight. Regarding productivity, all treatments differed significantly from the control. Treatments T7 and T2 did not differ significantly in productivity, indicating that under the edaphoclimatic conditions of the study, the difference in fertilization levels was not sufficient to influence productivity.

In treatment, T6, the full fertilization for both wheat and soybeans before wheat sowing resulted in higher yield and consequently an increase in productivity compared to other treatments. This suggests that early fertilization has a positive effect on final wheat productivity.

**Table 3. Average values of wheat productivity and hectoliter weight.**

| Treatments | Description | Wheat Productivity (kg $ha^{-1}$) | Hectoliter Weight (HW) |
|---|---|---|---|
| T1 | Control | 302.81 E | 58.75 c |
| T2 | 100% total wheat fertilization | 764.69 B | 67.50 ab |
| T3 | 100% total soybean fertilization | 463.37 D | 70.50 ab |
| T4 | 25% wheat + 75% soybean total fertilization | 583.12 C | 66.00 b |
| T5 | 75% wheat + 25% soybean total fertilization | 654.50 C | 69.00 ab |
| T6 | 100% total fertilization for wheat and soybean | 1007.19 A | 72.75 a |
| T7 | 50% wheat + 50% soybean total fertilization | 818.08 B | 68.25 ab |
| **Average** | | **656.25***  | **67.54**** |
| **CV (%)** | | 6.08 | 3.35 |

Letters in the same column indicate no statistical difference according to the Tukey test at 5% probability; ** and * = significant by the F test at 5% and 1% probability, respectively.

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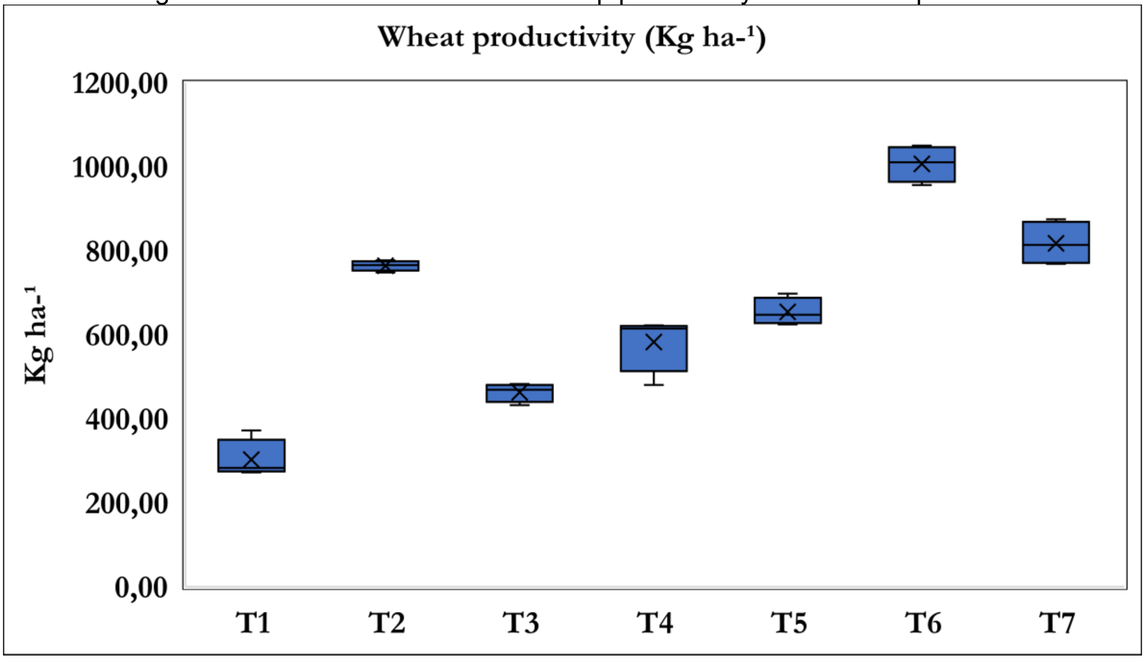
The comparative study between different fertilization treatments revealed significant variations in wheat productivity, expressed in kilograms per hectare. The results, shown in the boxplot graph (Figure 3), highlight that treatment T6 achieved the highest average productivity, followed by treatment T7, while treatment T1 showed the lowest average values. Greater dispersion was observed in treatments T4 and T7, indicating higher variability between these treatments.

Figure 3. Values obtained for wheat crop productivity in different replicates.




Corroborating these data in a study carried out by Carvalho (2021), it was noted that the anticipation of phosphate fertilization of the soybean crop, in black oats, even if broadcast in the winter crop, was effective in increasing its dry mass by 64%.

In a study carried out by Segatelli (2004), it was found that the application of phosphate and potassium fertilizers in soybean crops can lead to an increase in the agricultural productivity of the dry matter of the goosefoot grass after the sowing of Eleusine coracana (L.), Gaertn grass.

However, when comparing the final productivity averages to the national average of the 2024 harvest of 2,331 kg ha-1 and the average of the southern region of 1,930 kg ha-1 (CONAB, 2024), the results were extremely low and unsatisfactory. These results can be explained by the heavy rainfall that occurred in the state of Rio Grande do Sul during the wheat cultivation period, making it difficult to control the diseases and pathogens that affected the crop.

After statistical analysis of the average values of the hectoliter weight (HW) of the wheat crop, it was observed that all treatments differed from the control. However, there was no statistical difference between the other treatments, and they were not influenced by the different levels of fertilization in the wheat crop.

One of the parameters used to indirectly express the quality of wheat grains is the hectoliter weight (HW). This index refers to the mass of 100 liters of wheat, which is expressed in kg $hl^{-1}$. This parameter is influenced by the uniformity, shape, density, and size of the grains, and also by the amount of foreign matter and damaged grains in the sample, and is also used to identify the health of the grains (Miranda; Mori; Lorini, 2009). It is considered a quick test and indicator of quality.

According to Brasil (2005), wheat can be classified into Types 1 (PH 78), 2 (PH 75), and 3 (PH 70), according to the weight per hectoliter, moisture, foreign matter, impurities, and the percentage of damaged grains. Thus, with the results obtained from the pH in the experiment, only treatments T3 and T6 were classified as type 3 wheat. The other treatments did not reach the minimum pH for industrial marketing.

According to Ignaczak and Andrade (1982), a pH below 65 is considered waste and the rate of reduction of the minimum price of waste varies annually, normally left to the discretion of the cooperatives.

The hectoliter weight resulting from the comparison between the different fertilizations is presented in the boxplot graph (figure 4), highlighting that treatment T6 obtained the highest average productivity, followed by treatment T5, while treatment T1 presented the lowest average values. The observed dispersion was greater in treatments T4 and T5, indicating greater variability between these treatments.

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Figure 4. PH values obtained in the wheat crop in the different replicates.

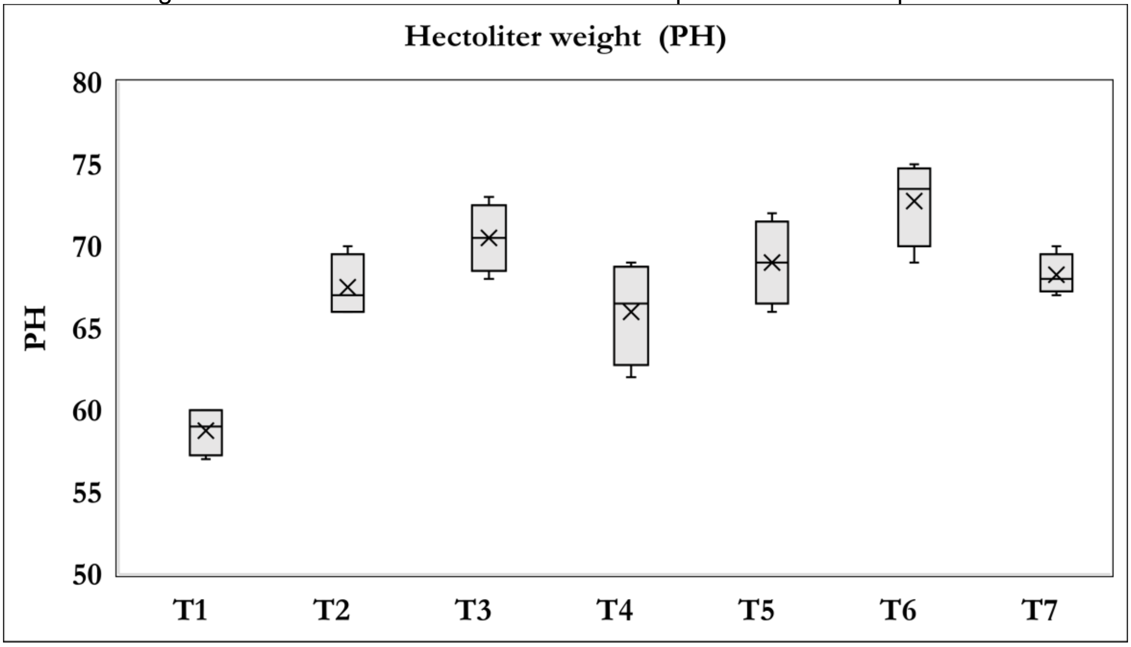


**Table 4** contains the average values of the lodging degree and plant height of soybeans subjected to different treatments. The average values of the lodging degree did not differ statistically from each other. However, when analyzing the treatments, it is noticeable that where fertilization was anticipated, whether partially or fully, a greater average lodging of the plants occurred. Nonetheless, there were no significant losses in grain quality and quantity produced in the experiment.

Gzergorczick (2018) mentions that the lodging of plants causes tissue rupture, disconnecting the vascular system of the stem, making recovery impossible, decreasing grain productivity, and creating difficulties in harvesting. Gruppi (2020) highlights the importance of certain characteristics in soybean cultivation, including high productivity potential, low lodging degree, and specific plant architecture features that facilitate mechanized harvesting, such as the height at which the first legume is inserted into the plant.

In the variable of soybean plant height, the treatments did not differ, demonstrating that this variable was not influenced by whether or not fertilization occurred during the crop cycle. Plant height is an important indicator identified by Taiz and Zeiger (2009) related to production, weed management, lodging, and harvesting efficiency. The development of its stature occurs when the stem elongates, as depending on the number and length of the internodes, this can or cannot happen.

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**Table 4.** Average values of lodging degree and plant height in soybean crop

| Treatments | Description | Lodging Degree | Plant Height (cm) |
|---|---|---|---|
| T1 | Control (Witness) | 1.00 | 76.40 |
| T2 | 100% total fertilization of wheat | 2.00 | 84.00 |
| T3 | 100% total fertilization of soybean | 1.75 | 82.80 |
| T4 | 25% wheat + 75% soybean total fertilization | 3.00 | 84.85 |
| T5 | 75% wheat + 25% soybean total fertilization | 2.50 | 87.35 |
| T6 | 100% total fertilization of both wheat and soybean | 2.00 | 87.32 |
| T7 | 50% wheat + 50% soybean total fertilization | 2.75 | 87.80 |
| Average | | 2.14 ns | 84.36 ns |
| C.V. (%) | | 41.37 | 6.31 |

*ns = not significant*

**Table 5** contains the average values for the following variables: branches per plant, number of pods, and number of grains per pod in the soybean crop. The observed results show that for the variable "number of branches," only treatment T6 stood out statistically compared to the control, indicating a positive and synergistic effect of the total anticipation of chemical fertilization in wheat on the soybean crop. A higher number of branches can favor a greater number of pod and grain insertions per plant.

**Table 5.** Average values for the number of branches per plant, number of pods per plant, number of grains per plant, and number of grains per pod in the soybean crop

| Treatments | Description | Branches | Num. Pods | Num. Grains | Num. Grains/Pod |
|---|---|---|---|---|---|
| T1 | Control (Witness) | 4.05 b | 83.20 | 166.05 | 2.00 |
| T2 | 100% total fertilization of wheat | 6.10 ab | 85.30 | 179.90 | 2.11 |
| T3 | 100% total fertilization of soybean | 5.25 ab | 91.45 | 192.10 | 2.10 |
| T4 | 25% wheat + 75% soybean total fertilization | 5.75 ab | 92.00 | 202.70 | 2.20 |
| T5 | 75% wheat + 25% soybean total fertilization | 5.15 ab | 84.70 | 176.30 | 2.08 |
| T6 | 100% total fertilization of both wheat and soybean | 6.11 a | 99.11 | 210.89 | 2.13 |
| T7 | 50% wheat + 50% soybean total fertilization | 5.40 ab | 80.35 | 173.35 | 2.16 |
| Average | | 5.40 * | 88.02 ns | 185.90 ns | 2.11 ns |
| C.V. (%) | | 17.31 | 16.92 | 15.78 | 18.58 |

*Letras iguais na mesma coluna não diferem entre si pelo teste de Tukey a 5% de probabilidade; = *significante pelo teste de F a 5% de probabilidade; ns= não significativo*

According to Floss (2019), for most soybean cultivars grown in Brazil, the number of grains per pod, which is the main yield component, depends on lateral branching. That is, the earlier the plant branches, the greater the number of axils per branch, and the higher the yield. In an experiment conducted by Silva (2023), the lowest values for soybean branching were found in the control and with the lowest dose of mineral fertilizer.

However, for the average values of the variables "number of pods," "number of grains," and "number of grains per pod" in the soybean crop, no influence from the

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anticipation of chemical fertilization in the wheat crop was observed. However, the treatment with total anticipation of the chemical fertilization reduced the number of mechanized operations in the successive wheat and soybean cycle, demonstrating that such a practice can be adopted to improve nutrient cycling and operational logistics in the wheat/soybean production system.

**Table 6** contains the average values related to soybean yield and the weight of a thousand grains. These results show that treatment T6 with a final average of 3,956 kg ha-1 was the only one to differ statistically from the control. However, Riferte (2021) demonstrated in a study on phosphorus anticipation that there was no increase in grain yield for maize and soybean with the anticipation of phosphorus fertilization.

**Table 6.** Average values for yield and thousand-grain weight in soybean crop

| Treatments | Description | Soybean Yield (kg ha-¹) | Thousand-Grain Weight |
|---|---|---|---|
| T1 | Control (Witness) | 3066.92 b | 149.34 b |
| T2 | 100% total fertilization of wheat | 3444.61 ab | 163.03 ab |
| T3 | 100% total fertilization of soybean | 3417.69 ab | 162.19 ab |
| T4 | 25% wheat + 75% soybean total fertilization | 3505.38 ab | 169.94 a |
| T5 | 75% wheat + 25% soybean total fertilization | 3462.30 ab | 170.20 a |
| T6 | 100% total fertilization of both wheat and soybean | 3956.15 a | 177.91 a |
| T7 | 50% wheat + 50% soybean total fertilization | 3758.46 ab | 172.22 a |
| Average | | 3515.93 * | 166.40 * |
| C.V. (%) | | 10.82 | 5.01 |

*Letras iguais na mesma coluna não diferem entre si pelo teste de Tukey a 5% de probabilidade; = *significante pelo teste de F a 5% de probabilidade.*

For the variable "thousand-grain weight," treatments with partial or total anticipation of chemical fertilization differed statistically from the control. However, treatments with conventional fertilization doses, where the fertilization was calculated separately for the crop's needs (T2 and T3), did not differ statistically from the control. On the other hand, Guareschi (2008) in a study on potassium fertilization anticipation in winter crops, found no difference between treatments where phosphorus fertilization was anticipated in soybeans, for the variables of thousand-grain weight, total number of pods per plant, and number of grains per pod.

In a study by Segatelli (2022), it was found that the anticipation of pre-sowing phosphorus and potassium fertilization in soybean along with the capim-pé-de-galinha did not affect the thousand-seed weight or agricultural yield of soybean.

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## CONCLUSION

The early use of fertilization for wheat and soybean before wheat sowing promoted positive performance in wheat yield and improved hectoliter weight quality for industrial commercialization.

The anticipation of chemical fertilization for soybeans in the wheat crop positively influenced the number of branches, productivity, and thousand-grain weight in the soybean crop.

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