Revista ARACÊ
ISSN: 2358-2472

EVALUATION OF ARBUSCULAR MYCORRHIZAL FUNGI IN THE PRODUCTIVE PHASE OF SOYBEAN ASSOCIATED WITH DIFFERENT DOSES OF PHOSPHORUS

https://doi.org/10.56238/arev7n2-228

Submitted on: 01/19/2025 **Publication date:** 02/19/2025

Ivaneide de Oliveira Nascimento[1], Gabriel Souza Santos[2], Júlio Oliveira Anastácio[3], Mario Soares da Silva Júnior[4], Thatyane Pereira de Sousa[5], Ruth de Abreu Araújo[6], Sheila Elke Araujo Nunes[7], Thiago Palhares Farias[8] and Jaqueline Lima da Conceição Souza[9].

[1] Dr. in Agroecology
State University of the Tocantina Region of Maranhão
E-mail: ivaneide@uemasul.edu.br
ORCID: https://orcid.org/0000-0001-7095-7092
LATTES: https://lattes.cnpq.br/5127803057876571
[2] Agronomist
State University of the Tocantina Region of Maranhão
[3] Agronomist
State University of the Tocantina Region of Maranhão
E-mail: aanastaciojulio07@gmail.com
LATTES: http://lattes.cnpq.br/1992349979438995
[4] Agronomist
State University of the Tocantina Region of Maranhão
E-mail: mariojr_soares@hotmail.com
LATTES: http://lattes.cnpq.br/0588733384143348
[5] Dr. in Agronomy
State University of the Tocantina Region of Maranhão
ORCID: https://orcid.org/ 0000-0003-3672-8506
LATTES: http://lattes.cnpq.br/ 9496191270626949
[6] Dr. in Plant Production
State University of the Tocantina Region of Maranhão
E-mail: rutha.araujo@uemasul.edu.br
ORCID: https://orcid.org/0000-0002-8745-2389
LATTES: http://lattes.cnpq.br/3453786734154071
[7] Dr. in Tropical Medicine and Public Health
State University of the Tocantina Region of Maranhão
E-mail: sheilanunes@uemasul.edu.br
ORCID: https://orcid.org/0000-0002-2309-7314
LATTES: http://lattes.cnpq.br/2570242039075491
[8] Dr. in Soil Science
Federal Institute of Maranhão
E-mail: thiagopalhares@ifma.edu.br
ORCID: https://orcid.org/0000-0001-8628-8196
LATTES: http://lattes.cnpq.br/5269074145020311
[9] Dr. in Agronomy
State University of Goiás
E-mail: jaqueline.souza@ueg.br
ORCID: https://orcid.org/0000-0003-1829-2665
LATTES: http://lattes.cnpq.br/0969910887801284

Revista ARACÊ
ISSN: 2358-2472

ABSTRACT

The present work focused on the action of arbuscular mycorrhizal fungi, which perform symbiosis with plant roots, helping them to absorb more nutrients. In this sense, this study consisted of an experimental verification, in which it was sought to evaluate the action of these fungi in the productive phase of soybean, associating them with different doses of phosphorus, in order to find out if this would be a viable alternative for the replacement of the base fertilizer. This substitution, it was believed, could improve productivity and reduce the costs of producing this oilseed. Regarding the methodology, it was an experimental field study, in which Rootella BR, which contains mycorrhizal fungus, was inoculated and associated with phosphorus in different dosages; considering that the study was divided into eight treatments, with and without fungi, and with different doses of P2O5. This material was analyzed using the qualitative-quantitative approach and the inductive method. It was noted as a result that, in fact, the association of arbuscular mycorrhizal fungi with phosphorus allowed a better development of the plant, especially its nutrition, which allowed an increase in this productivity. Still with regard to the results, it was noticed that the most successful treatments were those that contained more phosphorus.

Keywords: Fertilization. Grain. Glycine Max. Productivity.

Revista ARACÊ
ISSN: 2358-2472

INTRODUCTION

Soybean (*Glycine max* L. Merril) belongs to the legume family, being one of the most significant oilseeds today, produced all over the world, especially in China, the United States and Brazil (MÜLLER, 1981; SILVA, 2013; FERRARI et al., 2015; MILIOLI, 2021).

It is one of the most important inputs of Brazilian agriculture and has also become one of the main vectors of agribusiness development (HIRAKURI et al., 2018; RHODEN et al., 2020). However, it is not a native plant, on the contrary, it originated in China. Its introduction brought a lot of profitability to producers, both in Brazil and in the international market, as is the case in the United States (FONTES, 2019; PEREIRA, 2021).

In this context, Pará, where this research was carried out, is one of the major soybean producers, with at least three important producer centers, located in the Northeast (where the present field study was developed); South and West. In addition, agribusiness in the region has economic relevance, and a harvest of at least 2.35 million tons is expected for the years 2021/2022, according to data from the National Supply Company (AGENCIAPARA, 2021).

Despite the success of soybean cultivation in the state and in the country, it is also a fact that the demand is increasing more and more, as well as the need to increase production, both for the international market (especially Asia, but also Argentina, the European Union, Thailand and Egypt), as well as for the national market in full expansion. Due to this demand, it is noted that it is necessary to increase cultivation techniques and technology, in order to achieve better quality production at an increasingly lower cost, with a view to competitiveness (GAZZONI, 2018; RHODEN, 2020).

Thus, mycorrhizal fungi are an ally that can benefit soybean cultivation, since they associate with the roots, promoting a mutualistic symbiosis that both favors the development of the crop, as well as provides energy to the fungus itself. This association, in turn, is something natural in plants. Therefore, this type of fungus, especially the arbuscular ones, of the phylum Glomeromycota, which are formed by forming arbuscules, are naturally associated with the roots of these plants; it is also possible to introduce them artificially (BERBARA et al., 2006).

Santos et al. (2012) state that the relationships between water, soil, climate and plant are essential to agriculture and that the natural environment, when used correctly, can contribute significantly to plant development and increased production. In this sense, Pereira et al. (2013) point out that arbuscular mycorrhizal fungi are essential

Revista ARACÊ
ISSN: 2358-2472

microorganisms for plants in general and for soybeans in particular. For the authors, it is important to study them, understand their interaction and relationship with plants. For Vilela et al. (2013), these fungi help in the acquisition of macronutrients, especially phosphorus (P), calcium (Ca) and magnesium (Mg).

This is also what Tavares (2021) highlights, when they address that mycorrhizal fungi work as if they were a kind of extension of the roots and, in addition, help in the absorption of nutrients and favor water retention. All this benefits photosynthesis, the development of soybeans, increasing its productivity; which was also intended to be proven with the present experiment.

In view of the above, the objective of this work was to evaluate the action of arbuscular mycorrhizal fungi in the soybean production phase, associated with different doses of phosphorus.

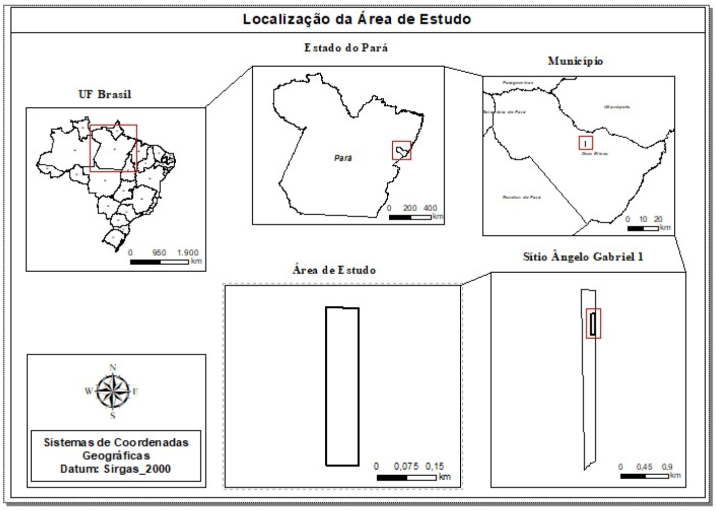
METHODOLOGY

The experiment was carried out in the municipality of Dom Eliseu – PA, a city located in the Northeast of the State of Pará and which has a very productive rural area in terms of soybean. This state is one of the major producers of this input, and in 2020 a significant volume of tons (119.4 million) was reached, according to IBGE data (2020). In addition, it is important to understand that the cultivated area in the state has been expanding, especially in the last 11 years 2010-2021, a period in which it went from 85.4 thousand to 731.9 hectares, with probabilities to expand even more in the future (AGENCIAPARA, 2021).

The specific site of this study was a commercial plantation area of Ângelo Gabriel Farm, Latitude 04°08'37" S; Longitude 47°49'21" W (Figure 1); which has a planting area of approximately 1ha (hectare), whose soybean was planted using cultivar 8644.

Revista ARACÊ
ISSN: 2358-2472

Figure 1. Map with location of the study area.



Source: Author, 2022.

The climate of the region is semi-humid tropical, according to the Köppen classification and its average temperature is 26.5º, with a rainfall of about 1,794 mm/year (Climatempo, 2021).

The experiment took place between January and May 2021 in a randomized block design, with eight treatments and four replications (Chart 1). The treatments were composed of: T1 – Treatment 1: 0 kg of P2O5 and absence of Rootella BR; T2 – Treatment 2: 133.2 kg of P2O5 and absence of Rootella BR; T3 – Treatment 3: 224 kg of P2O5 and absence of Rootella BR; T4 – Treatment 4346 kg of P2O5 and absence of Rootella BR; T5 – Treatment 5: 0 kg of P2O5 and presence of Rootella BR; T6 – Treatment 6: 133.2 kg of P2O5 and presence of Rootella BR; T7 – Treatment of 7224 kg of P2O5 and presence of Rootella BR; T8 – Treatment 8: 346 kg of P2O5 and presence of Rootella BR.

Soybean seeds were treated with the liquid and peat inoculant (Bioma Brady), the rooting (Aca Plus) and Trichoderma (StimuControl) – all of which are already farm-standard. In addition, Rootella BR, based on *Rhizophagus intraradices, was added to the T5 to T8 samples*.

The application of Rootella BR took place at the recommended dose of 120 g $^{ha-1}$. In addition, 120 mL $^{ha-1}$ of liquid inoculant (*Bradyrhizobium japonicum*), 240 g $^{ha-1}$ of peat, 100 mL $^{ha-1}$ of rooter, 100 mL $^{ha-1}$ of StimuControl (*Trichoderma harzianum*) were used, and 33 kg of seed ha-1 were used.

Revista ARACÊ
ISSN: 2358-2472

Table 1. Distribution of treatment in the 4 (four) blocks in the field.

BLOCK 1	BLOCK 2	BLOCK 3	BLOCK 4
T1	T1	T1	T1
T2	T2	T2	T2
T3	T3	T3	T3
T4	T4	T4	T4
T5	T5	T5	T5
T6	T6	T6	T6
T7	T7	T7	T7
T8	T8	T8	T8

Source: Author, 2021.

Planting was carried out using a nine-row seeder. This passed twice in each treatment, totaling nine meters of planted area width and 100 meters per block.

To proceed with the analysis of the experiment in the field, the collection of plant material was carried out, which consisted of the removal of pods in ten plants of each of the treatments/block. The count of pods per plant and grains per pod was carried out in order to verify possible increases in production. All data were annotated and transcribed into the Excel program, which were statistically analyzed.

To verify the final yield and to reach the necessary conclusions about the real benefits of mycorrhizal fungi in soybean production (Figure 2), a harvester (A) was used; a shoe scale (C) and an agricultural trailer (B/D).

Revista ARACÊ
ISSN: 2358-2472

Figure 2. Soybean harvest, harvester (A); shoe scale (C) and agricultural trailer (B/D).

Source: Author, 2021.

To carry out the weighing, the agricultural cart was placed on the footing in order to verify the weight of this instrument and at the end subtract it from the total. The harvester underwent the complete treatment, dumped the contents on the trailer and it was placed on the footing, which was done in each of the eight treatments.

All collected data were submitted to analysis of variance and to the Scott-Knott test at the level of 5 % probability, with the application of the statistical program Sisvar.

RESULTS

According to the analysis of the results obtained, it was observed that there was no significant difference at the level of 5% probability by the Scott-Knott test between the controls and the treatments, for the variables number of pods per plant (NVP), number of grains per pod for pods with 1, 2 and 4 grains (Table 1).

Revista ARACÊ
ISSN: 2358-2472

However, in the treatment with the highest dose of phosphorus (346 kg of P2O5 $^{ha-1}$) associated with the commercial product (Rootella BR) based on arbuscular mycorrhizal fungus, *Rhizophagus intraradices*, numerically provided the highest number of pods per plant (NVP). Thus, comparing the treatment with the same dosage (346 kg of P2O5 $^{ha-1}$) without the association with mycorrhizal fungus, it is observed that the highest dosage associated with the arbuscular mycorrhizal fungus, *Rhizophagus intraradices*, provided an increase of 88 pods per plant.

On the other hand, in the parameter pod with three grains (Vag3), it was observed that there was a statistically significant difference between the treatments and the control, in which the highest number of grains was obtained in the treatments with the highest dosage of phosphorus (346 kg of P2O5 $^{ha-1}$) with or without the association with the commercial product based on arbuscular mycorrhizal fungus, however, with the association of mycorrhizal fungi, there was a numerically higher number of grains per pod (Table 1).

Regarding productivity, there was a significant difference between the controls and the treatments, where the treatments with phosphate fertilization associated with AMF were the ones that presented the best averages and with significant variations when compared to the treatments without Rootella BR. Thus, the treatment with 346 kg of P2O5 $^{ha-1}$ with the commercial product based on *R. intraradices,* was statistically equal to the treatment with 224 kg of P2O5 $^{ha-1}$ with the commercial product based on *Rhizophagus intraradices*.

In this case, the lowest dosage of phosphate fertilizer associated with the commercial product based on *R. intraradices (*Rootella BR) *can be applied*. These treatments in relation to the treatments with 224 kg of P2O5 $^{ha-1}$ and 346 kg of P2O5 $^{ha-1}$ without association with mycorrhizal fungi promoted an increase of 424 kg and 444 kg, respectively, in the final production (Table 1).

The results presented demonstrate an interaction between the dosages of phosphate fertilizer and the mycorrhizal fungi, in this context the use of a product based on mycorrhizal fungi associated with lower dosages of phosphate fertilizer can be an alternative for the economy with phosphate fertilizer.

Revista
ARACÊ
ISSN: 2358-2472

Table 1. Evaluations related to soybean pods and yield, at different doses of phosphorus, with and without inoculation of Rootella BR based on *Rhizophagus intraradices*.

Treatments	NVP (Pcs.)	NGV (Unit)				Prod./ treatment (kg)
		Vag 1	Vag 2	Vag 3	Vag 4	
T1: 0kg P2O5 S/R	672,25 a	4,50 a	44,67 a	17,92 a	0,12 a	976,00 c
T2: 133,2 kg P2O5 S/R	700,25 a	5,33 a	45,72 a	18,80 a	0,17 a	1126,00 b
T3: 224 kg P2O5 S/R	618,00 a	5,47 a	38,3 a	17,90 a	0,12 a	842,00 c
T4: 346 kg P2O5 S/R	635,75 a	5,05 a	37,17 a	20,95 a	0,40 a	862,00 c
T5: 0kg P2O5 C/R	518,25 a	4,62 a	34,17 a	12,85 b	0,17 a	1012,00 b
T6: 133,2 kg P2O5 C/R	571,50 a	7,00 a	34,72 a	15,12 b	0,30 a	1104,00 b
T7: 224 kg P2O5 C/R	634,00 a	4,7 a	38,95 a	19,42 a	0,32 a	1284,00 a
T8: 346 kg P2O5 C/R	723,75 a	7,30 a	42,52 a	22,20 a	0,40 a	1286,00 a
CV (%)	12,52	33,96	15,42	16,90	67,84	0,00

Source: Author, 2022.

DISCUSSION

In the experimental work that was developed, it was noticed that the best average NVP (number of pods per plant) was that of treatment 8, with Rootella BR and the highest dose of P2O5; that is, in the treatment in which more phosphorus and mycorrhizal fungi were used. This result can probably be attributed to the fact that mycorrhizal fungi assist in phosphorus absorption (BERBARA et al., 2006; VILELA et al., 2013).

Balota et al. (2011) also developed a study in which they evaluated the inoculation of arbuscular mycorrhizal fungi in soils with different amounts of P, but in acerola seedlings. The authors concluded that these fungi are important for the development of plants and also in the increase of phosphorus content, especially where the dosages of this product are lower, which corresponds to the present work, since the productivity of treatment 8 is very close to treatment 7, which used less phosphorus, where they differ only by 2 kg.

The number of pods per plant decreases as phosphorus is reduced, and the use of Rootella BR seems innocuous, since there are fewer pods per plant. However, it can be seen that with this product, that is, with the action of mycorrhizal fungi, there was an increase in the number of grains per pod (NGV). In the same sense, there is the work of Bressan (2001), who analyzed the use of mycorrhizal fungi and phosphorus in the development of soybean. The author noticed that the inoculation of these fungi increased the leaf concentration of the elements nitrogen, phosphorus, potassium, zinc and copper; which also improved the development of these plants.

Finally, in relation to soybean yield, according to Bressan et al. (2001), the benefits of mycorrhizal fungi for this plant are great, precisely because they help to improve P nutrition, which is so essential for nodulation. In the present research, it was observed that,

Revista ARACÊ
ISSN: 2358-2472

in fact, the association of mycorrhizal fungi with phosphorus favored the increase in the amount of grains per pod (NGV), which, in turn, resulted in an increase in production.

CONCLUSION

It was found through the present experimental study about the use of arbuscular mycorrhizal fungi in the soybean production phase that their association with phosphorus allows a better development of the plant, causing an increase in productivity.

These fungi allow for better phosphorus absorption, as they increase the root absorption area. In this way, there is an improvement in the plant's nutrition. In this sense, the most successful treatments in the study were those that used inoculation of mycorrhizal fungi and higher doses of P_2O_5.

In view of the above, it is assessed that it is possible to replace the base fertilizer with the fungus associated with phosphorus, if the reduction in the amount of phosphorus is not extreme; since this nutrient is very important for the plant and cannot be suppressed.

ACKNOWLEDGMENTS

To the State University of the Tocantina Region of Maranhão, Center for Agrarian Sciences for all the support during the realization of this experiment.

Revista ARACÊ
ISSN: 2358-2472

REFERENCES

1. Agênciapará. (2022). Promotion of phytosanitary actions for soybean cultivation was a priority for Adepará in 2021. Available at: https://agenciapara.com.br/noticia/34315/. Retrieved on February 20, 2022.

2. Balota, E. L., Machineski, O., & Stenzel, N. M. C. (2011). Response of acerola to inoculation with arbuscular mycorrhizal fungi in soil with different phosphorus levels. Bragantia, Campinas, 70(1), 166-175.

3. Berbara, R. L. L., et al. (2006). Arbuscular mycorrhizal fungi: Far beyond nutrition. Viçosa: SBCS.

4. Bressan, W., et al. (2001). Mycorrhizal fungi and phosphorus in the growth, nutrient content, and production of intercropped sorghum and soybean. Pesquisa Agropecuária Brasileira, Brasília, 36(2), 315-323.

5. Climatempo. (2021). Climatology: Dom Eliseu PA. Available at: https://www.climatempo.com.br/climatologia/4872/domeliseu. Retrieved on February 20, 2022.

6. Ferrari, E., Paz, A., & Silva, A. C. (2015). Water deficit in soybean metabolism in early sowings in Mato Grosso. Nativa, 3(1), 67-77.

7. Fontes, A. V. (2019). Soybean industrialization process in Brazil [Undergraduate thesis, Federal University of Uberlândia]. Uberlândia-MG.

8. Gazzoni, D. L. (2018). Soybean in Brazil is driven by technological innovations. Ciência e Cultura, São Paulo, 70(3), 16-18.

9. Hirakuri, M. H., et al. (2018). Analysis of economic aspects regarding soybean grain quality in Brazil. Londrina: Embrapa Soja.

10. Milioli, A. S. (2021). Genetic gain in agronomic, phenological, and biochemical traits of soybean [Doctoral dissertation, Federal Technological University of Paraná]. Pato Branco-PR.

11. Müller, L. (1981). Taxonomy and morphology. In S. Miyasaka & J. C. Medina (Eds.), Soybean in Brazil (1st ed., pp.). Campinas: Instituto de Tecnologia de Alimentos.

12. Pereira, B. M. (2021). Technical-economic evolution of soybean production in Brazil and Argentina: A historical-comparative analysis [Master's dissertation, University of Brasília]. Brasília-DF.

13. Pereira, M. G., Santos, C. E. R. S., Freitas, A. D. S., Stamford, N. P., Rocha, G. S. D. C., & Barbosa, A. T. (2013). Interactions between arbuscular mycorrhizal fungi, rhizobia, and actinomycetes in the soybean rhizosphere. Revista Brasileira de Engenharia Agrícola e Ambiental, 17(12), 1249-1256.

14. Rhoden, A. C., et al. (2020). Analysis of supply and demand trends for soybean grain, meal, and oil in Brazil and major global markets. Desenvolvimento Em Questão, 18(51), 93-112.

15. Santos, F. L., et al. (2012). Agricultural hydrology. Évora: ICAAM.

16. Silva, R. R. (2013). Relationship between rainfall and soybean crop productivity in the municipality of Ibirubá [Master's dissertation, Federal University of Santa Maria]. Santa Maria-RS.

17. Tavares, G. G. (2021). Physiological changes in soybean plants subjected to water deficit levels and inoculation with arbuscular mycorrhizal fungi [Master's dissertation, Federal Institute of Education, Science and Technology Goiano]. Rio Verde-GO.

18. Vilela, L. A. F., et al. (2013). Native arbuscular mycorrhizal fungi in the acquisition of macronutrients by soybean cultivated in Cerrado Oxisol subjected to phosphorus doses. In XXXIV Brazilian Soil Science Congress, Florianópolis, 2013. Proceedings… Santa Catarina.