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Research Article

Basalt powder in the biodynamic bean cultivation system: a study in the city of Curitibanos-SC

Pó de basalto no sistema de cultivo biodinâmico do feijão: estudo no município de Curitibanos-SC

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ABSTRACT

This work sought to evaluate the effects of the use of basalt powder on the development of bean (Phaseolus vulgaris) crops in a biodynamic production system. The experiment, conducted in the field, in the biodynamic space of the Center for Rural Sciences (CCR) of the Federal University of Santa Catarina (UFSC), located in the city of Curitibanos-SC, was done through a Randomized Block Design (DBC) with three treatments: T1 control (without the use of basalt powder), T2 dosage of 2 t/ha of basalt powder and T3 dosage of 3t/ha of basalt powder. All treatments received the biodynamic preparations PB 500, Fladen and PB 501, in addition to the poultry litter at a dosage of 3 t/ha. The research methodology consisted of performing Analysis of Variance (ANOVA) and Tukey's Test to compare the plant height averages of each treatment after 30 days of planting and dry weight of harvested beans. In addition, Polynomial Regression Analysis was performed, along with the calculations of Maximum Technical Efficiency (TEM) and Maximum Economic Efficiency (MEE) to stipulate the optimal point of economic viability of the application of basalt powder. The results indicated that T2 and T3 showed higher initial vegetative growth (plant height) in comparison to T1; T3 differed from T1 in yield (weight of dry grains) and that the economic viability of using basalt powder in the biodynamic system, considering only the current prices of the input-output ratio, has its optimal point of TEM at 0.61 t/ha and MEE at 0.59 t/ha. With this, it is concluded that there are indications of positive effects of the application of basalt powder for bean yield in the biodynamic system and that the technical and economic feasibility studies need to be improved due to the slow pace of nutrient availability of basalt powder.

KEYWORDS: Biodynamic agriculture. Bean. Fertilization. Economic viability.

RESUMO

Esse trabalho buscou avaliar os efeitos da utilização do pó de basalto no desenvolvimento da cultura do feijão (*Phaseolus vulgaris*) em sistema de produção biodinâmico. O experimento, realizado a campo no espaço biodinâmico do Centro de Ciências Rurais (CCR) da Universidade Federal de Santa Catarina (UFSC), localizado no município de Curitibanos-SC, foi conduzido por meio do Delineamento em Blocos Casualizados (DBC) com três tratamentos: T1 testemunha (sem a utilização do pó de basalto), T2 dosagem de 2 t/ha de pó de basalto e T3 dosagem de 3t/ha de pó de basalto. Todos os tratamentos receberam os preparados biodinâmicos PB 500, Fladen e PB 501, além da cama de aviário na dosagem de 3 t/ha. A metodologia da pesquisa consistiu na realização de *Análises de Variância* (ANOVA) e do *Teste de Tukey* para comparar as médias dos tratamentos para a altura das plantas após 30 dias do plantio e para o peso seco do feijão colhido. Além disso foi realizada a *Análise de Regressão Polinomial* com a qual foram feitos os cálculos da Máxima Eficiência Técnica (MET) e da Máxima Eficiência Econômica (MEE) para estipular o ponto ótimo da viabilidade econômica da aplicação do pó de basalto. Os resultados indicaram que T2 e T3 apresentaram crescimento vegetativo inicial (altura das plantas) superior em relação a T1; que T3 diferenciou-se de T1 para a produtividade (peso dos grãos secos) e que a viabilidade econômica da utilização do pó de basalto no sistema biodinâmico, considerando-se somente os preços correntes da relação insumo-produto, possui seu ponto ótimo da MET em 0,61t/ha e da MEE em 0,59 t/ha. Com isso conclui-se que há indicativos de efeitos positivos da aplicação do pó de basalto para a produtividade do feijão no sistema biodinâmico e que os estudos de viabilidade técnica e econômica precisam ser aperfeiçoados em devido ao ritmo lento de disponibilidade dos nutrientes pelo pó de basalto.

PALAVRAS-CHAVE: Agricultura biodinâmica. Feijão. Fertilização. Viabilidade econômica.

INTRODUCTION

Food and nutrition security, which includes access to adequate quantity, diversity, and quality of food made available to people (FAO 2023) is one of the major problems of the twenty-first century, especially considering the context of climate change and demographic projections. In view of this, it is essential to foster resilient, efficient, and low-energy cost production systems to make healthy and nutritious food available to the population (LADERCHI et al. 2024). Considering aspects of the Brazilian food culture, beans (Phaseolus vulgaris) are one of the fundamental foods for food and nutritional security (BELIK 2020), being an important source of protein, iron and carbohydrates, which contribute to the arrangement of dishes with adequate nutritional balance (DOMENE et al. 2021).

Despite its importance for food and nutritional security, there has been a reduction in the cultivated area and number of rural establishments dedicated to this crop (IBGE 2006 and 2017), reflecting the cost-benefit ratio and opportunity costs offered by other crops. Most of the beans produced and consumed in Brazil are made in conventional production systems, based on synthetic mineral fertilizers, however, studies indicate that it is possible to produce it in systems such as agroecological, organic, biodynamic, among others, achieving similar yields (CARVALHO & WANDERLEY 2007, DARTORA et al. 2022), especially with poultry-based fertilization (PEREIRA 2015, PARIZOTTO et al. 2016). However, in recent years, remineralization with rock powder has proven to be an interesting alternative for the nutritional management of soil and for improving the productivity of agroecological production systems (SANTOS et al. 2015, REIS DE SÁ 2023).

The use of the so-called remineralizers based on ground rocks can provide soils with important and varied amounts of essential nutrients for plants, depending on the characteristics of the product used, with basalts being the most used rocks in southern Brazil to increase soil’s mineral reserve of (MARTINS et al. 2023). Basalt powder is an important source of minerals such as calcium (Ca), magnesium (Mg), iron (Fe), phosphorus (P), potassium (K) and silicon (Si), although the process of releasing these minerals occurs slowly and gradually (ALOVISI et al. 2021). In this sense, its use is conditioned to its combination with other sources of nutrients that have a more immediate release to plants. As it is a rock powder found in nature, basalt powder is compatible with agroecological production systems (MAPA 2011) including biodynamic systems.

In the biodynamic cropping system, agricultural production is based on the following principles: a) soil and plant nutrition is conceived as a broad process that takes place through the use of biodynamic compost, made from plant remains and animal manure available in the agricultural organism and which acts on the availability of organic matter and minerals for the soil and plants; b) the application of Biodynamic Preparations (PB 500, Fladen and PB 501): the first two are made from cattle manure, applied to the soil when planting crops and work as nutritional activators for plant growth, and the third, made from silica powder, is applied to plant flowering and works as an activator for the nutritional concentration of fruits and seeds (STEINER 2017, MIKLÓS 2019); c) the observation of the astronomical calendar, which serves as a guide to orient agricultural activities (THUN 1986); d) and crop rotation and integration that provides mutual benefits to crops (DEFUNE 2000).

Guided by the premise of the individuality of the agricultural organism, biodynamic agriculture seeks to strengthen the autonomy of resources and conduction of an agricultural economy with low economic and energy costs. That said, the main objective of this work is to analyze the effects of the use of basalt powder for bean cultivation within the biodynamic system in terms of productivity and economic viability.

MATERIAL AND METHODS

The biodynamic experimental area of the Center for Rural Sciences (CCR) of the Federal University of Santa Catarina (UFSC) is located at Latitude 27º16'25", Longitude 50º30'11" and at an altitude of approximately 1,100m above sea level. The area has been managed with biodynamic agriculture since 2019, applying crop integration management and the use of the biodynamic preparations mentioned above. The soil of the site can be characterized as typical Dystrophic Humic Cambisol and its analysis, done in 2022, presented the following indicators (Table 1):

Table 1. Soil analysis.

pH-H2O	SMP Index	Ca	Mg	Al	H+AL	CTC eft	Saturation Aluminum	Saturation Bases	
		....Cmol/dm3..................................							
5.4	5.3	5.84	3.27	0.80	9.70	10.56	7.58	50.17	
M.O	C.O	Clay	P-Mehlich	P- Resin	S	Na	K	pH7,0	K
.................%..................		....mg/dm3..						..Cmol/dm3..	
5.5	3.19	33	4.6	X	X	1	255	19.46	0.652
Cu	Zn	B	Fe	Mn	Ratios				
................................mg/dm3......................................					Ca/Mg	Ca+Mg/K	K/(Ca+Mg)1/2		
2.9	1.8	X	122.1	3.8	1.8	13.972	0.216		

The assembly of the experiment began in May 2023, with the Randomized Block Design (DBC), the application of basalt powder, and the sowing of rye. Basalt rock with the chemical composition in % of mass indicated in Table 2 was used as remineralizer.

For use in the treatments, the remineralizer was sieved through a mesh of 0.3 mm in diameter, obtaining the product classified as "filler", with faster weathering in relation to the other meshes. Due to the slow release of nutrients from the basalt powder, the rye crop served as a covering for the implementation of the bean crop in December 2023.

Table 2. Composition of basaltic rock remineralizer.

SiO_2	Al_2O_3	Fe_2O_3	P_2O_5	K_2O	MgO	CaO
52.20	13.86	14.10	0.85	2.63	3.44	8.16

The experiment was conducted using a Randomized Block Design (DBC), with three treatments and three replications, as shown in Table 3.

Table 3. Sketch of the experiment.

Block	T	T	T
B1	T1	T2	T3
B2	T2	T3	T1
B3	T3	T1	T2

The total area of bean cultivation, considering the internal and external borders, corresponded to 15.64m² (1.73m² for each treatment), with a density of 14 plants/m², following the guidelines of studies that stipulated this distribution (SILVA et al. 2008), thus accounting for 24 plants for each treatment.

The treatment was configured as shown in Table 4.

Table 4. Methodology for conducting the experiment.

Treatment	Characteristics
T1	Biodynamic preparations + 3 t/ha of poultry litter (witness)
T2	Biodynamic preparations + 3 t/ha of poultry litter + 2 t/ha of basalt powder
T3	Biodynamic preparations + 3 t/ha of poultry litter + 3 t/ha of basalt powder

The Biodynamic preparations PB 500 (antler-manure) and Fladen were applied at dosages of 300 and 200 g/ha respectively before sowing, whose function is to strengthen the capacity of nutrient absorption by the plant roots; PB 501 (antler-silica) was applied at a dosage of 10 g/ha during flowering, to act as a stimulator of fruit and seed nutrition (STEINER 2017).

The poultry litter used had the following composition: N 1.0%, C 20%, Moisture 25%, pH 8.3, CEC/c 17.0, CEC (mmol.c/kg) 340.0) and was applied before sowing, along with PB 500 and Fladen. Previous studies have recommended the use of up to 6t/ha for the cultivation of organic beans (PARIZOTTO et al. 2016), however, in order for this dosage not to interfere with the evaluation of basalt powder, the dosage of poultry litter was reduced to 3t/ha.

Regarding the dosages of basalt powder, while other studies have indicated results with dosages above 7t/ha (FERREIRA et al. 2023, GROSSELLI et al. 2024), it was decided to use lower dosages (T2= 2t/ha and T3= 3t/ha), as it is an area conducted with agricultural management that constantly seeks to revitalize the soil. The seeds used were from beans of the carioca variety, a seed that has been reproduced in the experimental area since 2019.

The following activities were performed to conduct the experiment: 12/07: application of poultry litter, PB 500, Fladen and bean sowing under the cover of rye straw; 12/20: manual weeding; 06/01: measurement of plant height; 01/10: manual weeding; 01/20: application of PB 501 before sunrise; 03/07: harvest; 03/10 drying in the shade until the grains reached a moisture content of 13%, when they were weighed on an analytical scale for evaluation.

The research methodology consisted of quantitative analysis of the averages of the treatments with different doses of basalt powder to evaluate the vegetative growth (height of the plants after 30 days of sowing), yield (weight of dry beans) and evaluations of technical and economic efficiency.

The data on plant height after 30 days of sowing, and harvested and dried beans was submitted to Analysis of Variance (ANOVA) of the treatments averages, to the Anderson-Darling test, to verify the normality of the samples, to the Tukey test, to compare the pairs of the averages at a 5% significance level of, and to the analysis of Polynomial Linear Regression, which served as the basis for the analyses of Maximum Technical Efficiency (TEM) and Maximum Economic Efficiency (MEE). All statistics were done with the assistance of the Minitab Statistical Program.

RESULTS AND DISCUSSION

The Anderson-Darling test indicated normality of the samples, both for the measurements of plant height and weight of the grains after drying (Table 5).

Table 5. Evaluation of vegetative growth (height of plants 30 days after planting).

Treatment	N	Average (cm)	Standard deviation	Grouping	Differences between levels	T-value	Adjusted P-value
T1	18	28.94	2.83	B	T2-T1	2.95	0.013
T2	18	31.83	3.29	A	T3-T1	3.63	0.002
T3	18	32.50	2.64	A	T3-T2	0.68	0.776

* Different letters indicate statistical differences at the significance level of 5%.

The analysis of plant height intended to evaluate the nutritional boost provided by the availability of basalt powder in the initial vegetative growth cycle of beans. The results indicate that there were significant differences in the averages of T3 and T2, with the use of basalt powder in the proportions of 3t/ha and 2t/ha, respectively, in relation to the averages of T1, without the use of basalt powder. Other studies that evaluated the effects of basalt powder on the vegetative growth of beans had positive results, however, with much higher dosages, such as 7.5t/ha (GROSSELLI et al. 2024) and above 20t/ha (FERREIRA et al. 2023), however, the comparisons in these cases were of basalt powder to synthetic fertilizers.

The fact that in this study the incorporation of basalt powder was done to the crop previous to the bean and the comparisons were made exclusively within the biodynamic management, made it possible to perceive its effects even with lower doses (Table 6).

Table 6. Yield assessment (dry grains weight).

Treatment	N	Average weight (g)	Standard deviation	Grouping	Differences between levels	T-value	Adjusted P-value
T1	3	303,7	43,7	B	T2-T1	1,10	0,549
T2	3	348	21,1	AB	T2-T3	2,84	0,066
T3	3	462,7	70,5	A	T3-T1	3,94	0,018

* Different letters indicate statistical differences at the significance level of 5%.

Regarding the weight of beans after drying, T3 showed significant effects for yield in comparison to T1. Other studies have indicated positive effects on bean yield with the use of basalt powder combined with fertilization using poultry litter at a dosage of 6t/ha (PLEWKA et al. 2009, SILVA et al. 2020) and at dosages above 2.5t/ha in studies compared with NPK-based mineral fertilization (LOMPA 2024). The results of this study are close to the results found in studies that also made comparisons within agroecological production system (SANTOS et al. 2015), which identified significant effects of the use of basalt powder starting at 4t/ha.

The total productivity for the area of 15.64m² was 3.343kg, which, when extrapolated, corresponds to 2,137kg/ha or 35.6 sacks/ha. For comparison purposes, the average productivity of carioca beans in Santa Catarina in the last three harvests, 2020/21, 2021/22 and 2022/23, was 1,684 kg/ha (EPAGRI/CEPA 2023) and in the municipality of Curitibanos it was 2,133 kg/ha (IBGE 2024). This signals the productive viability of the biodynamic system of bean cultivation using the basalt powder + poultry litter combination and converges with previous studies related to the cost-effective economic feasibility of biodynamic cultivation systems (BOSETTI et al. 2020).

To measure the Maximum Technical Efficiency (TEM) and Maximum Economic Efficiency (MEE) of the use of basalt powder in the different treatments, the Quadratic

Polynomial Regression Analysis ($y=b_0+b_1x+b_2x^2+\varepsilon$) was performed, in which y represents the dependent variable, yield/weight of bean grains; and x the independent variables, basalt powder doses; ε the standard deviation (ROSA et al. 2021). The analysis was performed using the Minitab Statistic software and resulted in the equation $y= 27.89x^2 – 33.44x + 303.7$. With this equation, the Δ, which represents the differences between the values of the variables, the TEM, which means the maximum amount of basalt powder used to obtain maximum productivity, and the MP, the maximum production achieved with the estimated optimal dosages, were calculated.

$$\Delta = b^2 - 4 * a * c = (-33{,}44)^2 - 4 * 27{,}89 * 303{,}7 = -32{,}76$$

$$\text{MET} = \frac{-b}{2a} = \frac{-(-33{,}44)}{2 * 27{,}89} = 0{,}60$$

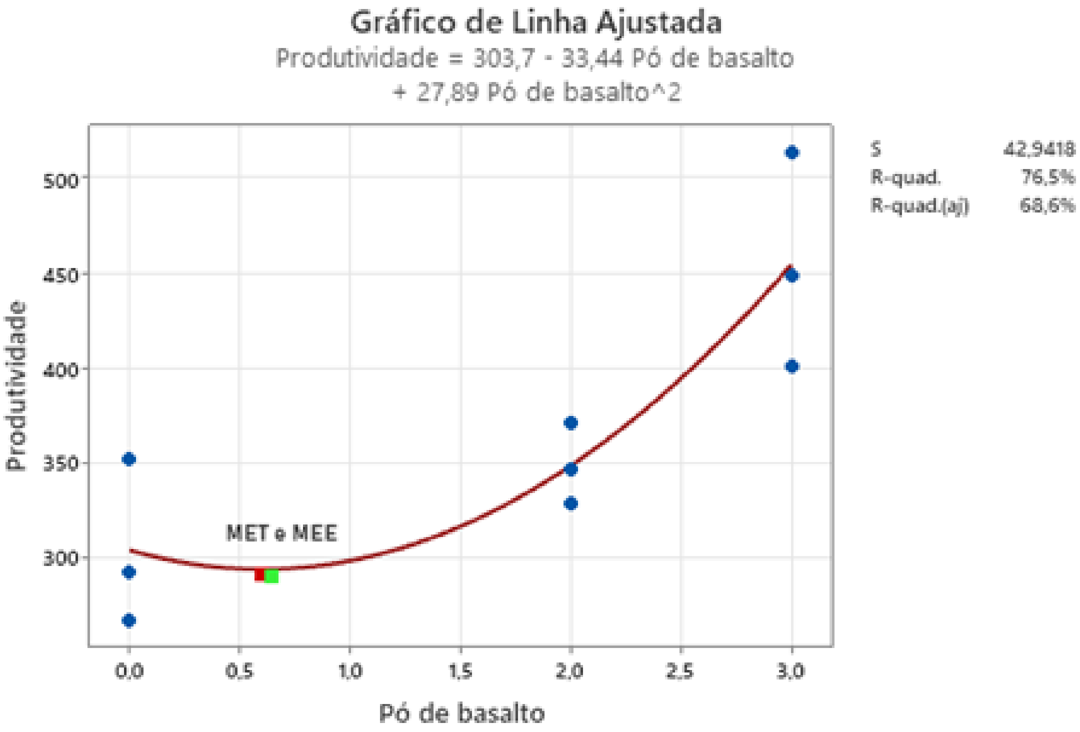
$$\text{MP} = \frac{-\Delta}{4 * a} = \frac{-(-32{,}76)}{4 * 27{,}89} = 0{,}2936$$

This means that the MET for the model would be the application of 0.60 t/ha of basalt powder, which would result in a maximum production (MP) of 2,936 kg/ha. For Maximum Economic Efficiency (MEE), the values of R$226.00 per 60 kg sacks of carioca beans (product w) and R$250.00 per ton of basalt powder (input t) at current prices quoted in mid-April 2024 (INFOAGRO 2024) were considered, which resulted in the MEE at a dosage of 0.59 t/ha.

$$MEE = \frac{(\frac{t}{w} - b)}{2a} = \frac{\left(\frac{250}{226} - 33{,}44\right)}{2 * 27{,}89} = 0{,}59$$

The MET indicators need to be relativized, due to the design of the experiment been restricted to only three treatments with basalt powder dosages (0.2.3 t/ha) and due to the fact that its release occurs slowly, which implies the need for measurement in subsequent harvests; the MEE also needs to be relativized due to the fluctuations in prices of the input (basalt powder) and the product (beans) (Figure 1).

Figure 1. Maximum Technical Efficiency (MET) and Maximum Economic Efficiency (MEE).



CONCLUSION

The use of basalt powder combined with poultry fertilizer responds satisfactorily to the bean crop in the biodynamic production system. The treatments with 2t/ha and 3t/ha of basalt powder showed significant effects in comparison to control for vegetative growth; while the treatment with 3t/ha was statistically superior to control in terms of productivity.

The production of beans within the biodynamic system achieved a result similar to the average of the conventional system for the municipality of Curitibanos-SC, therefore, it can be an alternative for farmers in the region. In turn, the Maximum Technical Efficiency (MET) and Maximum Economic Efficiency (MEE) analyses indicate an optimal use of basalt powder at an optimal point below the quantities tested in the experiment.

In this case, it is necessary to consider that the release of basalt powder occurs slowly and its effects can be observed in subsequent crops. Considering this, it is suggested to test other proportions of basalt powder dosages and evaluate their effects in subsequent harvests to measure their technical and economic feasibility with more refinement.

AUTHOR CONTRIBUTIONS

Conceptualization, methodology and formal analysis: Cleber José Bosetti; Antônio Lunardi Neto;
Software and validation: Cleber José Bosetti;
Investigation: Cleber José Bosetti; Antônio Lunardi Neto
Resources and data curation: Cleber José Bosetti; Antônio Lunardi Neto
Writing - preparation of the original draft: Cleber José Bosetti
Writing - review and editing: Cleber José Bosetti; Antônio Lunardi Neto
Visualization: Cleber José Bosetti; Antônio Lunardi Neto
Supervision: Cleber José Bosetti; Antônio Lunardi Neto

Project management: Cleber José Bosetti; Antônio Lunardi Neto
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Not applicable to studies that do not involve humans or animals.

INFORMED CONSENT STATEMENT
Not applicable as this study did not involve humans.

DATA AVAILABILITY STATEMENT
The data can be made available upon request.

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CONFLICTS OF INTEREST
We declare no conflicts of interest involving the publication of this article.

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