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# Vegetative Growth and Yield of Prostrate and Erect Peanut Cultivars Under Mb4 Stonemeal Application in the Brejo Region of Paraíba

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# VEGETATIVE GROWTH AND YIELD OF PROSTRATE AND ERECT PEANUT CULTIVARS UNDER MB4 STONEMEAL APPLICATION IN THE BREJO REGION OF PARAÍBA


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## Abstract

Peanut (*Arachis hypogaea* L.) is an oilseed crop of great economic importance worldwide. The cultivation of this and other crops demands sustainable fertilizers based on agroecological principles. Stonemeal is a practice that transforms rock materials into sources of soil supplementation and fertilization, benefiting natural systems. This study aimed to evaluate the vegetative growth and yield performance of three peanut cultivars under the application of MB4 rock dust. The experiment was set up in a randomized complete block design with a 3 × 2 factorial arrangement, consisting of three peanut cultivars (Runner IAC-886, BRS L-7, and BRS BR-1) and two MB4 treatments (with and without application), with four replicates. The Falker chlorophyll index, plant height, stem diameter, and yield components were assessed. Analysis of variance revealed significant cultivar effects for most variables and a significant cultivar × MB4 interaction only for stem diameter. However, MB4 application had no significant main effect on the evaluated variables.

**Keywords:** Peanut; *Arachis hypogaea* L.; Stonemeal technology; Soil remineralization; Yield components; Falker Chlorophyll Index.

## 1. Introduction

Peanut (*Arachis hypogaea* L.) is a legume crop cultivated in more than 100 countries and is recognized for its high adaptability to diverse soil and climatic conditions and its major economic importance. In addition to being an important source of income for farmers, peanut kernels have high nutritional value, being rich in proteins, lipids, minerals, vitamins, antioxidants, and bioactive compounds associated with health promotion and the prevention of chronic diseases (Raza et al. 2024). Globally, peanut production exceeds 50.4 million tonnes, with China accounting for approximately 37.7% of the total production. Brazil ranks eighth worldwide, with an estimated production of 1.16 million tonnes (USDA 2025).

In recent years, peanut cultivation has expanded considerably in Brazil. The cultivated area increased from 165.6 thousand to an estimated 282.1 thousand hectares throughout the historical series up to 2026, reflecting growing demand and the consolidation of the crop within the Brazilian agricultural sector (CONAB 2025). A similar trend has been observed in northeastern Brazil, where the cultivated area increased from 2.5 to 3.9 thousand hectares. In this context, the state of Paraíba has approximately 700 hectares under peanut cultivation, highlighting the crop's importance for family farming, income generation, and the diversification of regional production systems (CONAB 2025) .

Commercial peanut cultivars are classified into the Runner, Virginia, Spanish, and Valencia types, which belong to different subspecies of *A. hypogaea*. These groups exhibit distinct agronomic characteristics and are intended for both fresh consumption and the oil and processed food industries (De Santis et al. 2023). Despite its high adaptability to tropical conditions, peanut has high water requirements and is particularly sensitive to water deficit during the flowering, pod formation, and pod-filling stages. Water deficit impairs physiological processes, reduces vegetative growth, and limits crop yield (França et al. 2021). Furthermore, most available studies focus on upright-growth cultivars, which are still cultivated in relatively limited areas of Brazil, highlighting the need for further research involving cultivars under different growing conditions.

Although northeastern Brazil represents the country's second-largest peanut consumer market, mainly driven by consumption in coastal areas and during the traditional June festivals, regional production supplies only about 28% of the demand (Queiroga et al. 2018) . In the state of Paraíba, peanuts are marketed primarily through open-air markets and local fairs, where much of the production is processed by the farmers themselves through roasting and kernel processing, thereby

adding value to the product. This characteristic, together with the predominance of family farming, suggests that regional production may be higher than official records indicate, reinforcing the crop's importance for local socioeconomic development (Queiroga et al. 2018).

The sustainable expansion of agricultural production depends on the adoption of practices capable of reducing reliance on conventional mineral fertilizers, whose production is associated with high economic costs and environmental impacts. In this context, soil remineralization through the application of rock powder, known as stonemeal technology, has emerged as a promising alternative, particularly in highly weathered tropical soils (Theodoro et al. 2021). This technology gradually supplies nutrients, improves the chemical, physical, and biological properties of the soil, and contributes to the recycling of mining by-products, bringing the agricultural and mining sectors together within the principles of the circular economy and sustainable agriculture (Ramos et al. 2020).

In Brazil, stonemeal technology has received increasing attention because of the country's heavy reliance on imported fertilizers and the need for more sustainable strategies to maintain soil fertility (Korchagin et al. 2019; Manning & Theodoro 2020). Brazil's remarkable geodiversity favors the use of different soil remineralizers adapted to regional soil and climatic conditions, capable of gradually replenishing essential nutrients and improving soil attributes such as pH, cation exchange capacity, and nutrient availability (Locatelli et al. 2026; Swoboda et al. 2022; Burbano et al. 2022).

Among the available soil remineralizers, MB4 stands out as a product obtained by mixing biotite schist and serpentinite in a 1:1 ratio. This material is characterized by its high silica content and slow nutrient release, particularly of potassium, magnesium, and other elements essential for plant growth (Tito et al. 2019). Studies have shown that MB4 application can increase cation exchange capacity, contribute to the gradual correction of soil acidity, improve soil physical structure, and enhance nutrient availability, representing a sustainable alternative to conventional fertilizers (Aquino et al. 2020; Krahl et al. 2022; Viana et al. 2021). However, despite advances in the use of soil remineralizers in different crops, studies evaluating their effects on the agronomic performance of peanut cultivars, particularly under the soil and climatic conditions of northeastern Brazil, remain scarce.

Therefore, this study aimed to evaluate the vegetative growth and yield performance of three peanut cultivars (*A. hypogaea* L.) subjected to MB4 application in the Brejo region of Paraíba, Brazil. The hypothesis was that the use of this soil remineralizer would improve the gradual availability of nutrients in the soil, thereby promoting greater plant growth and productivity of the evaluated cultivars.

## 2. Materials and Methods

### *2.1 Study area*

The experiment was conducted at the experimental field of the Agriculture Sector, Center for Human, Social and Agricultural Sciences (CCHSA), Federal University of Paraíba (UFPB), Campus III, located in the municipality of Bananeiras, Paraíba, Brazil (6°45′10″ S, 35°37′41″ W; 526 m above sea level). According to the Brazilian Soil Classification System (SiBCS), the soil in the experimental area is classified as a Dystrophic Yellow Oxisol (Embrapa 2018), characterized by a high degree of weathering, good drainage, high porosity, and adequate permeability, attributes favorable for root development and agricultural management.

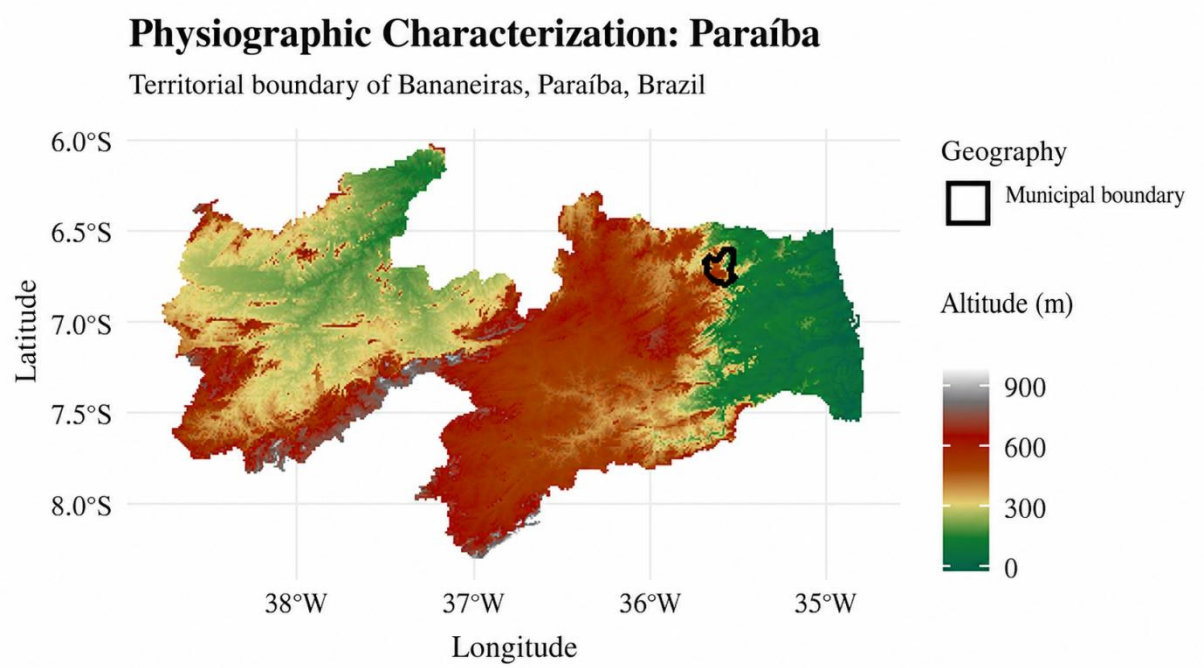


**Fig. 1** Location of the experimental area in the municipality of Bananeiras, Paraíba, Brazil, overlaid on a Digital Elevation Model (DEM), showing its location within the Brejo region of Paraíba. Source: IBGE and NASA SRTM.

### *2.2 Soil and soil remineralizer characterization*

Soil samples were collected for chemical characterization to determine soil fertility, following the methodology described by Teixeira *et al.* 2017. The samples were air-dried, gently crushed, passed through a 200-mesh sieve, and analyzed at the Soil Laboratory of CCHSA/UFPB.

The soil presented the following chemical properties: pH ($H_2O$) = 6.44; P = 8.64 mg $dm^{-3}$; K = 0.12 $cmol_c$ $dm^{-3}$; Na = 0.16 $cmol_c$ $dm^{-3}$; Ca = 3.10 $cmol_c$ $dm^{-3}$; Mg = 1.50 $cmol_c$ $dm^{-3}$; $Al^{3+}$ = 0.00

$cmol_c\ dm^{-3}$; $H^+ + Al^{3+}$ = 5.78 $cmol_c\ dm^{-3}$; Zn = 1.03 mg $dm^{-3}$; S = 16.70 mg $dm^{-3}$; sum of bases = 4.88 $cmol_c\ dm^{-3}$; cation exchange capacity = 10.65 $cmol_c\ dm^{-3}$; base saturation = 45.79%; and organic matter = 30.19 g $kg^{-1}$.

The soil remineralizer used was MB4, consisting of a 1:1 mixture of biotite schist and serpentinite, with nominal concentrations of 10% Mg and 5% Si (MIBASA 2023). The product, obtained from the municipality of Arapiraca, Alagoas, Brazil, has the following chemical composition: 39.73% $SiO_2$, 17.82% MgO, 5.90% CaO, 0.84% $K_2O$, 0.075% $P_2O_5$, 0.18% S, 7.10% $Al_2O_3$, 6.86% $Fe_2O_3$, 1.48% $Na_2O$, 0.074% Mn, 0.029% Cu, 0.029% Co, and 0.03% Zn (Aquino et al. 2020).

MB4 was applied at a rate of 700 g per experimental plot, equivalent to 1,750 kg $ha^{-1}$, and incorporated into the soil 30 days before sowing. During this period, supplemental irrigation was applied to promote weathering and gradual mineral dissolution, since water availability directly influences nutrient release from soil remineralizers (Van Straaten 2006).

### *2.3 Experimental design*

The experiment was conducted in a randomized complete block design (RCBD) with a 3 × 2 factorial arrangement and four replications. The factors were three peanut cultivars (*A. hypogaea* L.)—one with a prostrate growth habit (Runner IAC-886) and two with an erect growth habit (BRS L-7 and BRS BR-1)—and two MB4 fertilization treatments (with and without MB4 application).

Seeds of the three peanut cultivars (Runner IAC-886, BRS L-7, and BRS BR-1) were purchased from family farmers in the district of Cajá, municipality of Caldas Brandão, state of Paraíba, Brazil (approximately 7°10′25″ S, 35°20′28″ W). No plant material was collected from wild populations.

### *2.4 Experimental establishment and crop management*

Total rainfall during the crop cycle was 661.4 mm, distributed as follows: 187.8 mm during crop establishment, 115.5 mm during vegetative growth, 110.3 mm during flowering and fruiting, and 247.8 mm during pod filling (AESA 2023).

An irrigation system was installed to supply potential crop water requirements; however, it was used exclusively during the period between MB4 application and sowing. During this interval, microsprinklers operated for two hours in the morning and two hours in the afternoon.

The experimental area consisted of 24 plots of 4 m² each, with four planting rows spaced 0.50 m apart and 0.20 m between plants. Sowing was performed 30 days after MB4 application using three seeds per planting hole at a depth of 4–6 cm. Twenty days after seedling emergence, plants were thinned to 40 plants per plot. All evaluations were carried out using plants located within the net plot area.

Cultivars BRS L-7 and BRS BR-1 were harvested 90 days after sowing, whereas Runner IAC-886 was harvested after 110 days. Although this cultivar normally has a growth cycle ranging from 130 to 150 days, harvest was brought forward because of the incidence of late-season pests and diseases that compromised plant survival under field conditions (Godoy et al. 2005).

### *2.5 Biometric, physiological, and yield assessments*

Biometric assessments included plant height and stem diameter. Plant height was measured using a graduated ruler (cm), whereas stem diameter was measured with a digital caliper (mm).

Relative chlorophyll content was determined using a ClorofiLOG® chlorophyll meter, and chlorophyll *a*, chlorophyll *b*, and total chlorophyll were expressed as the Falker Chlorophyll Index (FCI). Measurements were taken approximately 30 days before harvest for each cultivar (Falker 2022).

Yield was estimated from the following yield components: number of pods per plant, pod mass per plant, grain yield (t $ha^{-1}$), and 100-seed weight (Santos et al. 2009). For these evaluations, 16 plants from the net plot area of each experimental plot were sampled. Seeds used for the 100-seed weight determination were manually removed from the pods and weighed after shelling.

### *2.6 Statistical analysis*

Biometric (plant height and stem diameter), physiological (Falker Chlorophyll Index), and yield data were subjected to analysis of variance (ANOVA) using the F-test. Residual normality was assessed using the Shapiro–Wilk test. When significant differences were detected, means were compared using Tukey's test at the 5% probability level. All statistical analyses were performed using RStudio (Posit Team 2024).

### *2.7 Use of artificial intelligence tools*

During manuscript preparation, the authors used the generative artificial intelligence assistant Claude Sonnet 5.5 (Anthropic 2026) to support the formatting of the reference list according to the journal style, to draft and revise the declaration statements (data availability, ethics, and permissions), and to apply editorial revisions to the manuscript file. The tool was not used to collect, analyze, or interpret the experimental data, or to generate the results and conclusions, and all statistical analyses were performed as described in Section 2.6. All content produced with the assistance of the tool was reviewed, verified, and edited by the authors, who take full responsibility for the final content of the manuscript.

## 3. Results

Mean chlorophyll index values and the results of the analysis of variance are presented in Table 1. Cultivar had a significant effect on chlorophyll *a*, chlorophyll *b*, and total chlorophyll index (FCI) ($p < 0.05$). Cultivar Runner IAC-886 showed the highest chlorophyll *a* values, which were statistically similar to those of BRS BR-1, whereas BRS L-7 exhibited the lowest values. A similar pattern was observed for chlorophyll *b*, with Runner IAC-886 presenting higher values than the other cultivars, which did not differ significantly from each other.

The total chlorophyll index followed the same trend observed for chlorophyll *a* and *b*, with the highest values recorded for Runner IAC-886, followed by BRS BR-1 and BRS L-7. In contrast, MB4 application did not significantly affect chlorophyll *a*, chlorophyll *b*, or total chlorophyll index ($p > 0.05$). Likewise, no significant interaction between cultivar and MB4 application was detected for any of the evaluated variables, indicating that cultivar responses were independent of the application of the soil remineralizer.

Table 1. Mean values of chlorophyll *a*, chlorophyll *b*, and total chlorophyll indices (FCI) in three peanut cultivars (*A. hypogaea* L.) treated with MB4 soil remineralizer.

| ***Treatments*** | Chlorophyll *a* (FCI) | Chlorophyll *b* (FCI) | Total Chlorophyll (FCI) |
|---|---|---|---|
| Runner IAC-886 With MB4 | 38.42 | 15.6 | 54.02 |

| | | | |
|---|---|---|---|
| Runner IAC-886 Without MB4 | 38.5 | 15.64 | 54.14 |
| BRS L-7 With MB4 | 34.99 | 12.17 | 47.16 |
| BRS L-7 Without MB4 | 35.09 | 12.34 | 47.43 |
| BRS BR-1 With MB4 | 36.46 | 12.96 | 49.41 |
| BRS BR-1 Without MB4 | 37.16 | 13.74 | 50.91 |
| | | | |
| ***Cultivars*** | | | |
| Runner IAC-886 | 38.46a | 15.62a | 54.08a |
| BRS L-7 | 35.04b | 12.25b | 47.29b |
| BRS BR-1 | 36.81a | 13.35b | 50.16b |
| | | | |
| ***MB4 Application*** | | | |
| With MB4 | 36.62a | 13.59a | 50.2a |
| Without MB4 | 36.92a | 13.9a | 50.82a |
| ***ANOVA (p-value)*** | | | |
| Cultivar (C) | <0.0006 | <0.00005 | <0.00016 |

| | | | |
|---|---|---|---|
| Application (A) | 0.6025 | 0.4603 | 0.5272 |
| C × A | 0.8718 | 0.7583 | 0.816 |
| CV (%) | 3.69 | 7.42 | 4.68 |

Means followed by the same letter within a column do not differ significantly according to Tukey's test at the 5% probability level.

Principal component analysis (PCA) (Figure 2) showed that the first principal component (PC1) explained 97.6% of the total data variance, indicating that chlorophyll *a*, chlorophyll *b*, and total chlorophyll index were the variables that contributed most to cultivar differentiation. The vectors for the three variables were strongly and positively correlated, indicating similar behavior among the chlorophyll indices. The score distribution showed that Runner IAC-886 was positioned in the direction of the chlorophyll vectors, corroborating the results presented in Table 1 and confirming its higher chlorophyll indices compared with BRS BR-1 and BRS L-7. In contrast, BRS BR-1 and BRS L-7 clustered in regions with lower PC1 scores, reflecting their lower chlorophyll index values. The confidence ellipses for BRS BR-1 and BRS L-7 overlapped considerably, indicating greater similarity between these cultivars, whereas the clear separation of Runner IAC-886 suggests a distinct physiological profile. No consistent separation was observed between treatments with and without MB4 application within each cultivar, indicating that MB4 had little influence on chlorophyll index variability and that cultivar was the primary factor explaining the distribution of treatments in the PCA.

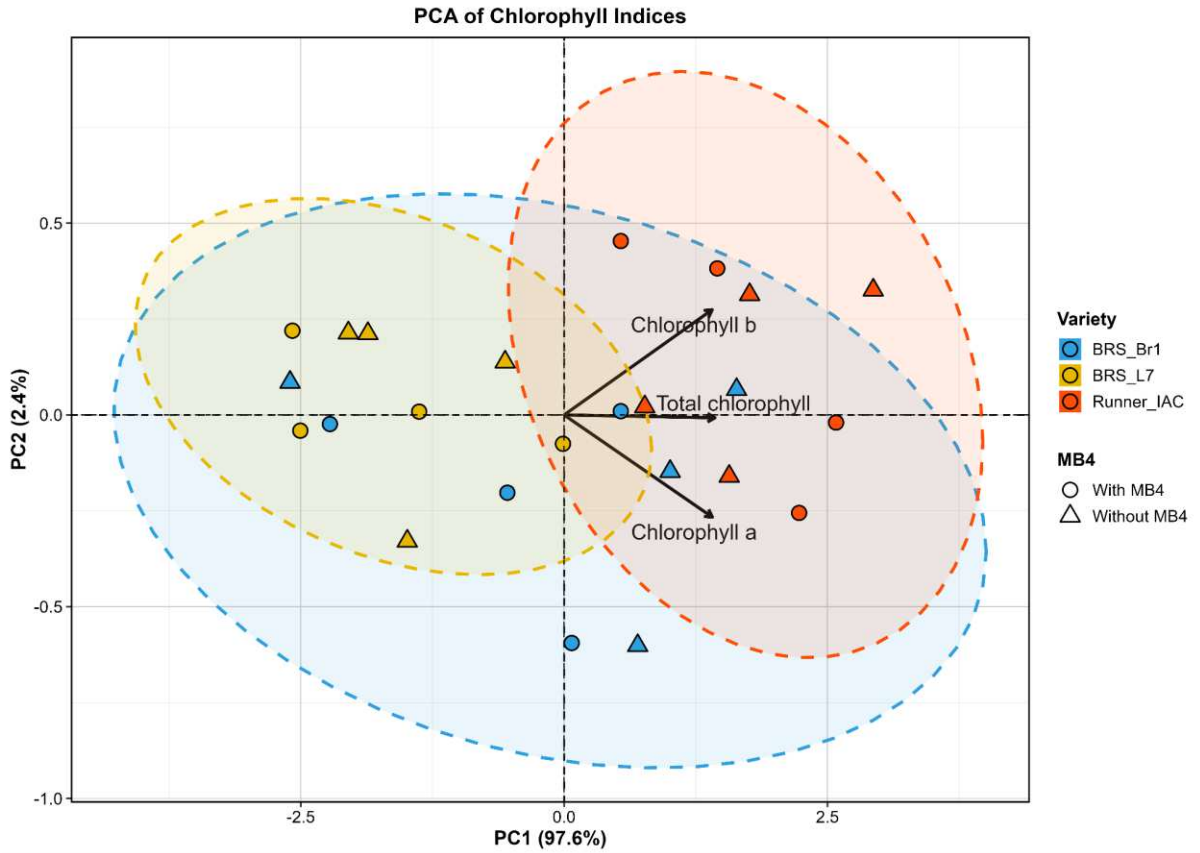


**Fig. 2** Principal Component Analysis (PCA) of chlorophyll *a*, *b*, and total indices in peanut cultivars (*A. hypogaea* L.) subjected to application or not of the MB4 soil remineralizer. Points represent experimental units; ellipses indicate cultivar grouping; circles represent treatments with MB4 and triangles represent treatments without MB4.

Mean plant height and stem diameter values for peanut cultivars with and without MB4 application are presented in Table 2. For plant height, a significant effect was detected only for cultivar ($p < 0.0001$), reflecting inherent morphological differences among the genetic materials. Because the cultivars have distinct growth habits (runner and upright), direct comparisons among them are not biologically meaningful. MB4 application did not significantly affect plant height ($p = 0.100$), although Runner IAC-886 showed a numerical increase when grown with the remineralizer.

For stem diameter, a significant cultivar × MB4 application interaction was observed ($p = 0.0176$), indicating that the response to the soil remineralizer depended on the cultivar. Among cultivars, Runner IAC-886 (4.09 to 4.13 mm) and BRS L-7 (4.89 to 4.93 mm) showed a numerical increase in stem diameter with MB4 application, whereas BRS BR-1 exhibited a numerical decrease (5.40 to 4.89 mm) compared with its untreated control. Despite these differences, the effects of the remineralizer on vegetative growth were minimal, and the observed variability was primarily determined by the genetic characteristics of the cultivars.

Table 2. Plant height and stem diameter of peanut cultivars (*A. hypogaea* L.) treated with MB4 soil remineralizer.

| **Treatments** | Plant height (cm) | Stem diameter (mm) |
|---|---|---|
| Runner IAC-886 With MB4 | 18.38 | 4.13 |
| Runner IAC-886 Without MB4 | 16.31 | 4.09 |
| BRS L-7 With MB4 | 36.44 | 4.93 |
| BRS L-7 Without MB4 | 39.14 | 4.89 |
| BRS BR-1 With MB4 | 43.25 | 4.89 |
| BRS BR-1 Without MB4 | 50.88 | 5.4 |
| ***Cultivars*** | | |
| Runner IAC-886 | 17.34c | 4.11c |
| BRS L-7 | 37.79b | 4.91b |
| BRS BR-1 | 47.06a | 5.14a |
| ***MB4 Application*** | | |
| With MB4 | 32.69a | 4.65a |
| Without MB4 | 35.44a | 4.79a |
| ***ANOVA (p-value)*** | | |

| | | |
|---|---|---|
| Cultivar (C) | <0.0001 | <0.0001 |
| Application (A) | 0.1 | 0.1033 |
| C × A | 0.0700 | 0.0176 |
| CV (%) | 11.43 | 4.18 |

Means followed by the same letter within a column do not differ significantly according to Tukey's test at the 5% probability level.

Mean values of yield components of peanut cultivars subjected to MB4 application are presented in Table 3. Cultivar had a significant effect on all yield variables ($p < 0.05$), whereas MB4 application and the cultivar × application interaction did not significantly influence the number of pods per plant, pod mass per plant, grain yield, or 100-seed weight ($p > 0.05$).

Cultivar Runner IAC-886 outperformed the other cultivars, recording the highest means for number of pods per plant (26.76), pod mass per plant (29.73 g), grain yield (2.94 t $ha^{-1}$), and 100-seed weight (60.25 g). Cultivars BRS L-7 and BRS BR-1 exhibited lower values for these variables and were statistically similar for number of pods per plant, pod mass, and grain yield. However, for 100-seed weight, the three cultivars differed significantly from one another, with Runner IAC-886 ranking highest, followed by BRS L-7 and BRS BR-1.

The graphs in Figure 3 corroborate the analysis of variance, showing that MB4 application did not promote significant changes in the yield components of the evaluated cultivars. Within each cultivar, treatments with and without the remineralizer showed similar data distributions, confirming the absence of a significant interaction. Thus, differences in yield attributes were predominantly determined by cultivar genetics rather than by MB4 application under the conditions of this study.

Table 3. Number of pods per plant, pod mass per plant, grain yield, and 100-seed weight of peanut cultivars (*A. hypogaea* L.) treated with MB4 soil remineralizer, Bananeiras, PB, 2023.

| **Treatments** | Pods (N/plant) | Pod mass (g/plant) | Yield (t $ha^{-1}$) | 100-seed weight (g) |
|---|---|---|---|---|

| | | | | |
|---|---|---|---|---|
| Runner IAC-886 With MB4 | 26.07 | 29.17 | 2.881 | 61.231 |
| Runner IAC-886 Without MB4 | 27.46 | 30.3 | 2.992 | 59.262 |
| BRS L-7 With MB4 | 18.94 | 22.85 | 2.257 | 53.734 |
| BRS L-7 Without MB4 | 17.79 | 19.65 | 1.941 | 49.812 |
| BRS BR-1 With MB4 | 17.46 | 18.19 | 1.797 | 35.004 |
| BRS BR-1 Without MB4 | 17.51 | 19.28 | 1.904 | 35.264 |
| ***Cultivars*** | | | | |
| Runner IAC-886 | 26.76a | 29.73a | 2.937a | 60.246a |
| BRS L-7 | 18.37b | 21.25b | 2.099b | 51.773b |
| BRS BR-1 | 17.49b | 18.74b | 1.850b | 35.134c |
| ***MB4 Application*** | | | | |
| With MB4 | 20.82a | 23.41a | 2.312a | 49.99a |
| Without MB4 | 20.92a | 23.08a | 2.279a | 48.113a |
| ***ANOVA (p-value)*** | | | | |
| Cultivar (C) | <0.00001 | <0.00003 | <0.00003 | <0.00001 |
| Application (A) | 0.9093 | 0.8184 | 0.8184 | 0.225 |

| | | | | |
|---|---|---|---|---|
| C × A | 0.4822 | 0.3768 | 0.3768 | 0.5294 |
| SEM | 0.983 | 1.236 | 0.122 | 2.313 |

Means followed by the same letter in the column do not differ by Tukey's test ($p < 0.05$). SEM = standard error of the mean.

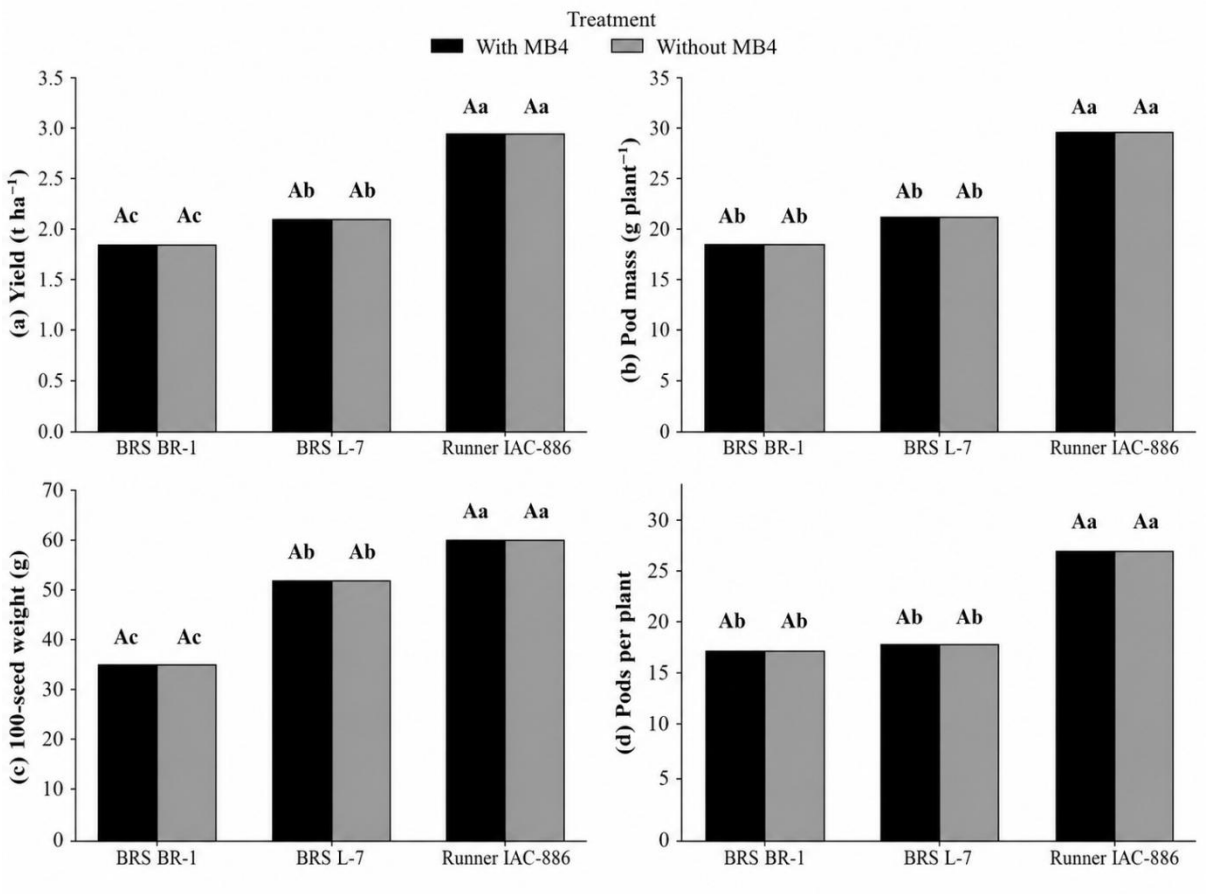


**Fig. 3** Yield components of peanut cultivars (*A. hypogaea* L.) subjected to application of the MB4 soil remineralizer: (a) grain yield (t $ha^{-1}$); (b) pod mass per plant (g); (c) 100-seed weight (g); and (d) number of pods per plant. Bars represent means of treatments with and without MB4 application. Lowercase letters compare cultivars within each application condition, while uppercase letters compare treatments with and without MB4 within each cultivar, by Tukey's test ($p \leq 0.05$). The absence of distinct letters indicates no significant difference between treatments.

The Pearson correlation matrix (Figure 4) revealed positive associations among all evaluated variables. The strongest correlations were observed between grain yield, number of pods per plant,

and pod mass per plant, indicating a tight relationship among the main yield components. In contrast, chlorophyll indices (*a*, *b*, and total) showed moderate positive correlations with yield variables, suggesting that, although these indices reflect plant physiological status, they were less strongly associated with yield variables than components directly linked to pod and kernel formation.

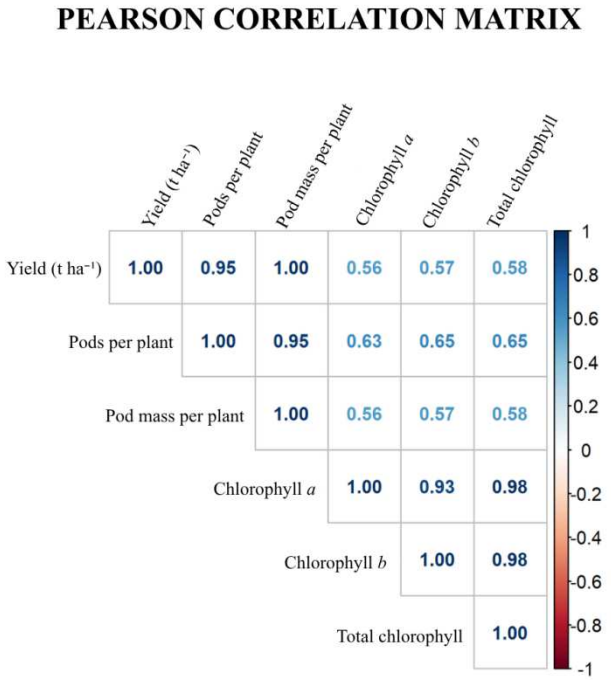


**Fig. 4** Pearson correlation matrix between yield components and chlorophyll indices in peanut cultivars (*A. hypogaea* L.). Color intensity represents the strength of the correlation, ranging from −1 to +1.

Principal component analysis (PCA) of yield variables and chlorophyll indices (Figure 5) showed that PC1 explained 78.6% of total data variability and was strongly influenced by yield components. PC2 accounted for 19.3% of the variance and was mainly associated with chlorophyll indices. The vectors of the yield variables were highly and positively correlated, confirming a strong association among yield components. Similarly, the chlorophyll indices clustered together, indicating high correlation among these physiological variables. However, the vector arrangement revealed only a moderate association between chlorophyll indices and yield components, corroborating the Pearson correlation results (Figure 4). These findings indicate that, although plant physiological status is related to yield performance, chlorophyll indices alone do not account for most of the variation observed in the yield of the evaluated cultivars.

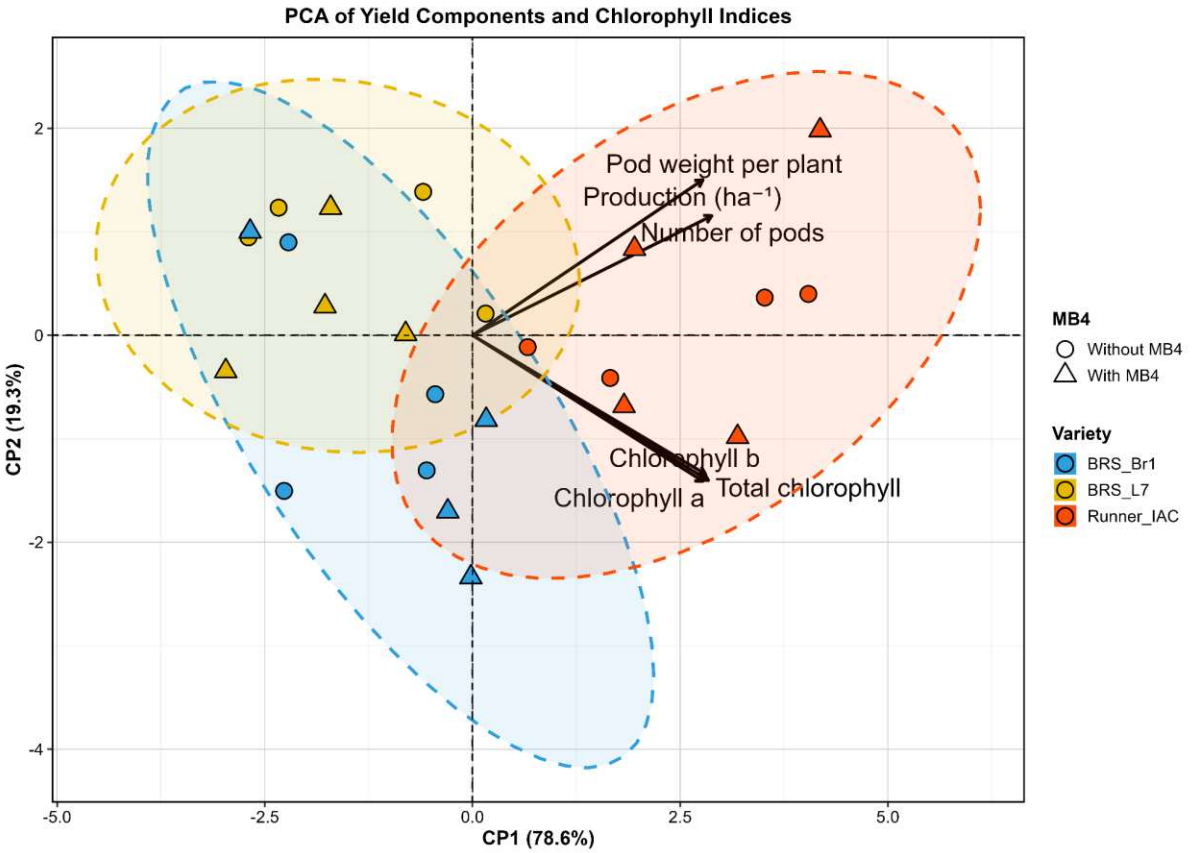


**Fig. 5** Biplot of principal component analysis (PCA) considering yield variables and chlorophyll indices in different peanut cultivars. Arrows represent the contribution and direction of variables in the multivariate ordination, while points correspond to individual samples. Colors and ellipses indicate cultivar grouping.

## 4. Discussion

The main finding of this study was that the application of the MB4 soil remineralizer did not significantly affect chlorophyll indices, vegetative growth, or yield components of the evaluated peanut cultivars. In contrast, the observed differences were predominantly determined by the genetic characteristics of the cultivars, indicating that, under the edaphoclimatic conditions of the Brejo region of Paraíba and at the applied dose (1,750 kg $ha^{-1}$), agronomic performance was mainly influenced by genotype rather than by soil remineralization.

The higher chlorophyll indices observed in cultivar Runner IAC-886 reflect intrinsic genotypic differences in the capacity to synthesize and maintain photosynthetic pigments. Chlorophyll *a* acts directly in the reaction centers of the photosystems, whereas chlorophyll *b* broadens the light absorption spectrum by integrating the light-harvesting complexes (LHC), thereby facilitating energy transfer to chlorophyll *a* (Taiz & Zeiger 2013; Taiz et al. 2017; Wang & Grimm 2021). Therefore, the

higher total chlorophyll index observed in Runner IAC-886 suggests a greater capacity for light energy capture, a characteristic that may have contributed to its superior yield performance. However, correlation analysis and PCA showed that this association was only moderate, indicating that chlorophyll indices alone do not explain the cultivar's superior yield performance. These results reinforce that yield results from the integration of several physiological, morphological, and genetic processes operating throughout the crop cycle.

Although magnesium is the central atom of the chlorophyll molecule and plays an essential role in photosynthesis, enzyme activation, and photoassimilate transport (Azarpazhooh et al. 2026; Meng et al. 2022), its presence in the MB4 composition was not sufficient to increase chlorophyll indices. This lack of response may be related to the low dissolution rate of the silicate minerals present in the remineralizer. Unlike soluble fertilizers, remineralizers release nutrients gradually, depending on the intensity of physical, chemical, and biological weathering processes in the soil (Theodoro 2020; Swoboda et al. 2022). Therefore, during the relatively short peanut growing cycle, the release of magnesium and other nutrients was likely insufficient to alter the nutritional status of the plants.

In addition to the short growing cycle of the cultivars, soil chemical conditions may also have limited the efficiency of the remineralizer. The soil had a pH of 6.44, which is close to neutrality, a condition that reduces the dissolution rate of primary minerals compared with more acidic soils (Primavesi 2002). This behavior is particularly relevant for minerals such as biotite, one of the constituents of MB4, whose geochemical weathering occurs slowly and may require years to release substantial amounts of nutrients (Melo and Alleoni 2009). Consequently, the effects of soil remineralization tend to become more evident in long-term crops or in agricultural systems managed over successive cropping cycles, where the residual effects of the applied material can accumulate (Theodoro 2020).

Similar results were reported by Brito *et al*. 2019, who observed limited responses to rock dust application in short-term evaluations, attributing this behavior to the slow nutrient release from remineralizers. In contrast, studies conducted over successive cropping cycles or using higher rock dust application rates have demonstrated improvements in soil fertility, greater nutrient availability, and increased crop productivity (Swoboda et al. 2022; Van Straaten 2006). These findings indicate that the agronomic efficiency of rock dust application depends on the interaction among application rate, particle size, mineralogical composition, soil biological activity, water regime, and the residence time of the material in the soil.

The superior yield performance of cultivar Runner IAC-886 confirms the strong influence of genetic background on the agronomic traits of peanut. This cultivar showed higher values for number of pods, pod mass, grain yield, and 100-seed weight, results consistent with its prostrate growth habit and greater capacity to produce reproductive branches. Cultivars belonging to the Runner group (*A. hypogaea* subsp. *hypogaea*) generally exhibit higher yield potential than upright cultivars, mainly because of their greater number of gynophores and more efficient use of the available growing area (Bakal et al. 2020; Godoy et al. 2001; Godoy et al. 2005). This characteristic explains why Runner IAC-886 maintained superior performance even in the absence of a response to the remineralizer.

The multivariate analyses further supported this interpretation. PCA clearly separated cultivar Runner IAC-886 from cultivars BRS BR-1 and BRS L-7 with respect to both chlorophyll indices and yield-related variables, whereas treatments with and without MB4 showed substantial overlap. Likewise, the correlation matrix revealed a strong association among yield components, particularly grain yield, number of pods, and pod mass, confirming that these variables are the primary determinants of yield performance. In contrast, chlorophyll indices showed only moderate correlations with yield, suggesting that physiological differences related to photosynthetic pigments account for only part of the factors responsible for cultivar performance.

The yields obtained in this study were consistent with those previously reported for cultivars BR-1, BRS L-7, and Runner IAC-886 in different regions of Brazil (Domingues da Silva et al. 2018; Oliveira et al. 2010), indicating that climatic conditions during the experiment were favorable for crop development. Total rainfall of approximately 661 mm was well distributed throughout the growing season, meeting the water requirements of peanut and reducing the likelihood of water deficit. Under these conditions, the absence of a response to MB4 further suggests that nutrient release kinetics exerted a greater influence than possible environmental constraints.

A limitation of this study was that the remineralizer was evaluated over only a single growing season, which may not have been sufficient to fully express the benefits of rock dust application. In addition, neither post-application soil nutrient availability nor foliar nutrient analyses were performed to quantify plant uptake of elements released from MB4. Such information would provide a more comprehensive understanding of the mechanisms underlying the lack of agronomic response observed.

Taken together, these results demonstrate that cultivar choice was the primary determinant of the physiological and yield performance of peanut under the edaphoclimatic conditions of the Brejo region of Paraíba. Cultivar Runner IAC-886 exhibited greater agronomic potential, whereas the MB4 soil remineralizer, at the application rate and evaluation period adopted in this study, did not

significantly affect plant growth or yield. These findings indicate that long-term studies involving different application rates, particle sizes, and successive applications of remineralizers are needed to adequately assess the potential of rock dust application for peanut cultivation in tropical soils.

## 5. Conclusions

Under the edaphoclimatic conditions of the Brejo region of Paraíba, application of the MB4 soil remineralizer at a rate of 1,750 kg $ha^{-1}$ did not significantly affect chlorophyll indices, vegetative growth, or yield components of the evaluated peanut cultivars during a single growing season. In contrast, physiological and yield performance was strongly influenced by genotype, with cultivar Runner IAC-886 standing out by exhibiting higher chlorophyll indices, greater pod number and pod mass, higher grain yield, and greater 100-seed weight than cultivars BRS L-7 and BRS BR-1.

Correlation analysis and PCA showed that yield-related variables formed a strongly correlated group, whereas chlorophyll indices showed only moderate associations with this group. These findings indicate that the superior yield performance of cultivar Runner IAC-886 is primarily attributable to its genetic characteristics rather than to the application of the remineralizer.

The results suggest that the agronomic effects of MB4 may require a longer period for nutrient release, which is an inherent characteristic of soil remineralizers. Therefore, long-term studies involving successive cropping cycles, different application rates and particle sizes, as well as evaluations of nutrient dynamics in both soil and plants, are needed to better understand the potential of rock dust application in peanut cultivation.

## Declarations

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**Competing Interests**: The authors declare that they have no competing interests relevant to the content of this article.

**Ethics approval and consent to participate**: Not applicable to human participants or animals. The study used cultivated peanut (*Arachis hypogaea* L.) cultivars grown in the experimental field of the

Federal University of Paraíba, and the plant material was handled in compliance with relevant institutional, national, and international guidelines and legislation.

**Permissions for plant material**: The seeds were purchased from family farmers, and the experiment was carried out on land belonging to the authors' institution (Federal University of Paraíba). Therefore, no specific permits or licences were required for the collection or use of the plant material.

**Data Availability:** The datasets generated and analyzed during the current study are available in the Mendeley Data repository: Estefene, Marcos (2026), "Vegetative growth and yield of prostrate and erect peanut cultivars under MB4 stonemeal application in the Brejo region of Paraíba", Mendeley Data, V1, https://doi.org/10.17632/p9dmyyvwdb.1

**Author Contributions**: Marcos Estefene Alves de Almeida conducted the experiment, performed the statistical analyses, and drafted the manuscript. Manoel Alexandre Diniz Neto and Belisia Lucia Moreira Toscano Diniz supervised the research. Everton de Oliveira Teixeira performed the soil analyses. Wanderley Feitosa Viana assisted with the statistical analyses. José Tavares de Freitas assisted with data collection and crop management. Vivi Sena Cruz assisted with data collection and harvesting. Victor Herbert de Alcântara Ribeiro translated and edited the manuscript. Adriano Salviano Lopes edited and critically reviewed the manuscript. All authors read and approved the final version of the manuscript.

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