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Diatomaceous Earth as a Silicon Source for Mango Trees in the Submiddle São Francisco Valley

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Abstract

OBJECTIVE:

To evaluate the effects of diatomaceous earth application as a source of silicon (Si) on gas exchange and the nutritional status of mango trees (Mangifera indica L.) cv. ‘Palmer’ grown under semiarid conditions in the São Francisco Valley.

MATERIAL AND METHODS:

Mango trees (Mangifera indica L.) cv. ‘Palmer’ were subjected to diatomaceous earth application as a silicon (Si) source. Treatments consisted of an untreated control and soil applications of diatomaceous earth (50 and 100 kg ha^{-1}), either alone or combined with foliar spraying (1 and 2%). Leaf samples were collected at two phenological stages to determine macronutrient, sodium (Na), and Si concentrations. Gas exchange was evaluated to determine the effects of Si application on plant photosynthetic activity.

RESULTS:

Diatomaceous earth application affected only stomatal conductance, reducing it by up to 24% during the first production cycle, without altering CO_2 assimilation rate, transpiration, or chlorophyll indices. Leaf P concentrations were not affected, whereas N, K, Ca, Mg, and S showed responses that depended on phenological stage and production cycle. The highest Si dose increased leaf Ca and Mg concentrations, reduced S concentrations, and decreased Na accumulation by up to 33.6%. Leaf Si concentrations did not consistently increase with diatomaceous earth application. Mango yield was not affected by the treatments in either production cycle.

CONCLUSION:

Diatomaceous earth application as a Si source promoted specific adjustments in the physiology and nutritional status of ‘Palmer’ mango trees, without increasing leaf Si concentrations or yield. Under the irrigated conditions of the Submiddle São Francisco Valley, its effects were limited, suggesting greater potential for use under conditions of more intense abiotic stress.

INTRODUCTION

Brazil holds a prominent position in global mango production, ranking as the seventh-largest producer worldwide and among the leading exporters of the fruit [1]. This performance is mainly supported by irrigated production in the São Francisco Valley, a region responsible for more than 93% of Brazilian mango exports and characterized by high productivity and year-round fruit supply [2]. In 2024, mango was the fresh fruit with the highest export value in the country, generating revenue exceeding US$350 million. In the same year, national production reached approximately 1.4 million tonnes, an increase of 7.1%, while productivity increased by 4.5%. Consequently, gross production value reached BRL 1.6 billion, representing a 22.7% increase compared with the previous year [3].

The São Francisco Valley has a tropical semiarid climate characterized by high temperatures, intense solar radiation, low rainfall, and high evaporative demand [4]. Although these conditions enable continuous mango production and confer high competitiveness on the region, they also favor the occurrence of abiotic stresses that may reduce photosynthetic efficiency, alter nutritional status, and compromise crop development and productivity [5–6]. In addition, irrigation depth must be reduced during the period preceding floral induction, an essential practice for flowering uniformity that temporarily intensifies water deficit imposed on the plants [7–8].

Silicon (Si), although not classified as an essential element, is widely recognized as a beneficial element because it increases plant tolerance to abiotic and biotic stresses and is considered an important tool for crop management in semiarid

environments [9–10]. Its application promotes morphophysiological and biochemical changes that reduce water loss through transpiration, increase water-use efficiency, preserve photosynthetic pigments, and strengthen plant tissues through silica deposition in cell walls [11–12]. Consequently, greater stability of the photosynthetic apparatus, maintenance of stomatal conductance and CO_2 assimilation, improved nutritional balance, and greater tolerance to heat, intense solar radiation, and water deficit may occur [13].

In this context, diatomaceous earth (DE) stands out as a natural and potentially efficient Si source for agricultural use. It is an amorphous sedimentary rock of biogenic origin, formed through the deposition and fossilization of diatom frustules, unicellular microalgae belonging to the phylum Bacillariophyta, over thousands to millions of years in continental and marine aquatic environments [14]. DE consists predominantly of amorphous silica (SiO_2) and also contains small amounts of other elements such as sodium (Na), magnesium (Mg), and iron (Fe) [15]. Its physical properties, including high porosity, large surface area, low density, high permeability, and low thermal conductivity, provide high water- and nutrient-retention capacity and favor gradual Si solubilization in the soil [10,16]. These characteristics make diatomaceous earth a promising alternative to conventional Si sources, with potential to increase Si availability in soil, favor plant uptake, and contribute to mitigating environmental stress, particularly in agricultural systems established in semiarid regions [17].

Considering the economic and social importance of mango production in the São Francisco Valley and the need to develop strategies that increase the sustainability of production systems under semiarid conditions, this study aimed to evaluate the effects of diatomaceous earth application as a Si source, applied to the soil alone or in combination with foliar sprays, on physiological responses and the nutritional status of mango trees (Mangifera indica L.) cv. ‘Palmer’. The hypothesis was that Si application would mitigate the effects of abiotic stresses characteristic of the region, favoring maintenance of photosynthetic activity and plant nutritional balance.

MATERIALS AND METHODS

2.1 Characterization of the Experimental Area

The experiment was conducted in a commercial orchard of mango (Mangifera indica L.) cv. ‘Palmer’ over two production cycles, from July 2021 to June 2022 (first cycle) and from July 2022 to May 2023 (second cycle). The experimental area was located at Andorinhas Farm, Senador Nilo Coelho Irrigated Perimeter, Petrolina, Pernambuco, Brazil (9°27'15" S; 40°36'51" W; 392 m altitude), in the Submiddle São Francisco Valley. The regional climate is classified as hot semiarid (BSh) according to Köppen–Geiger, with a mean annual temperature of 26.0°C and mean annual rainfall of 459 mm [18].

During the experimental period, rainfall, air temperature, and relative humidity data were obtained from an automatic weather station installed in the experimental area, allowing characterization of the environmental conditions to which the plants were exposed during the two production cycles (Fig. 1).

Before treatment application in each experimental cycle (2021/2022 and 2022/2023), soil samples were collected at a depth of 0.00–0.20 m to characterize the soil fertility attributes of the experimental area (Table 1). Leaf samples were also collected and analyzed for macronutrients, silicon (Si), and sodium (Na) to characterize the initial nutritional status of the plants (Table 2).

Table 1
Soil chemical attributes in the 0.00–0.20 m layer of the experimental area before treatment application in the two production cycles, Andorinhas Farm, Petrolina, PE, Brazil.

Cycle	pH	MO	P	K+	Na+	Ca2+	Mg2+	Al3+	(H + Al)	SB	V
	H2O	g_kg1	mg_dm³	---------- cmolc dm³ ----------							%
2021–2022	6,97	20,4	22,7	0,23	0,04	5,70	1,03	0,0	0,62	7,12	92
2022–2023	6,79	21,5	26,2	0,21	0,04	5,78	1,03	0,0	0,61	6,99	91

OM = soil organic matter; SB = sum of bases. Extractants: P: resin; K^+ and Na^+: Mehlich ($HCl + H_2SO_4$); Ca^{2+}, Mg^{2+} and Al^{3+}: KCl.

Table 2
Leaf concentrations of macro- and micronutrients, silicon, and sodium in ‘Palmer’ mango before treatment application in the two evaluation cycles, Petrolina, PE, Brazil.

	N	P	K	Ca	Mg	S	Si	Na	Fe	Cu	Mn	Zn	B	Mo
	g kg-1								mg kg-1					
2021–2022	16,1	1,5	11,02	22,83	2,57	1,29	1,28	0,095	45,71	29,50	121,21	26,58	78,18	0,63
2022–2023	15,4	1,4	6,0	26,4	1,95	1,52	1,56	0,109	68,76	28,34	104,35	30,96	63,54	0,58

2.2 Experimental Design

The experiment was conducted in a randomized block design with five treatments and five replicates, with each experimental plot consisting of five plants. Treatments were: T1 – control (without silicon application); T2–50 kg ha⁻¹ diatomaceous earth (DE) applied to the soil; T3–50 kg ha⁻¹ DE applied to the soil + 1% foliar DE application; T4–100 kg ha⁻¹ DE applied to the soil; and T5–100 kg ha⁻¹ DE applied to the soil + 2% foliar DE application. The doses were established based on previous studies showing positive responses to Si application in fruit crops [19–21].

Diatomaceous earth was used as the silicon source and contained 88.55% SiO_2, 4.05% Al_2O_3, 0.37% Fe_2O_3, 0.18% SO_3, 0.14% TiO_2, and 0.06% K_2O. Considering the Si content of the source, treatments corresponded to the following Si doses: T2 and T3, 44.28 kg ha⁻¹ Si applied to the soil; T4 and T5, 88.55 kg ha⁻¹ Si applied to the soil. For foliar treatments, suspensions containing 17.71 and 35.42 g L⁻¹ Si were used for T3 and T5, respectively.

Diatomaceous earth was manually broadcast onto the soil surface within the area effectively wetted by the microsprinkler system, corresponding to the canopy projection. The product was uniformly distributed within an approximate radius of 1.5 m from the trunk, covering the region with the highest concentration of absorbing roots. This application strategy was intended to maximize Si availability in the root absorption zone, favor gradual solubilization, and facilitate transport by irrigation water.

Soil-applied doses were split into two applications, with 50% applied during shoot maturation and the remaining 50% during fruit development in both crop cycles.

For foliar treatments, a spray volume of 700 L ha⁻¹, equivalent to approximately 2 L per plant, was used. Six sprays were performed per cycle, three during shoot maturation and three during fruit development, at seven-day intervals. Spraying was performed to provide uniform canopy coverage and maximize contact of the suspension with the leaf surface, thereby favoring Si absorption.

2.3 Gas Exchange and Chlorophyll Indices

Physiological evaluations were performed 40 days after application of 50% of the soil-applied diatomaceous earth (DE) dose and after the third foliar spray, which was applied at seven-day intervals. This period coincided with the shoot maturation stage, characterized by reduced irrigation depth as a management practice for floral induction. This condition intensifies temporary plant water deficit and allows assessment of silicon (Si) effects on crop physiological responses.

Gas exchange was determined on fully expanded, physiologically active leaves located in the middle third of the canopy using a portable infrared gas analyzer (IRGA), LCi Portable Photosynthesis System® (ADC BioScientific Ltd., Hoddesdon, UK), under a photosynthetically active photon flux density of 1,800 µmol m^{-2} s^{-1}. Net CO_2 assimilation rate (A, µmol CO_2 m^{-2} s^{-1}), stomatal conductance (gs, mol H_2O m^{-2} s^{-1}), and transpiration rate (E, mmol H_2O m^{-2} s^{-1}) were evaluated. On the same leaves, relative chlorophyll a and b indices were determined using a portable ClorofiLOG® CFL 1030 chlorophyll meter (Falker Automação Agrícola, Porto Alegre, Brazil)

2.4 Determination of Leaf Macronutrient, Silicon, and Sodium Concentrations

Leaf samples were collected to determine macronutrient, sodium (Na), and silicon (Si) concentrations. Sampling was performed at two phenological stages: 90 days after the first treatment application, during shoot maturation, and at the preharvest stage. In each experimental plot, 20 leaves were collected, corresponding to four leaves per plant, one from each canopy quadrant. Leaves were collected from the middle portion of the canopy, from the most recent fully mature vegetative flush, according to [22].

After collection, samples were placed in paper bags and sent to the Plant Soil™ Soil and Leaf Chemical Analysis Laboratory, where they were washed with deionized water, dried in a forced-air oven at 65°C for 72 h, and subsequently ground in a Wiley mill.

Nitrogen (N) concentration was determined according to [22] after sulfuric digestion of 0.2 g dry matter at 350°C [30]. Phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), and sodium (Na) were determined in extracts obtained by nitric-peroxide digestion (HNO_3:H_2O_2; 3:1) in a microwave digestion system (Milestone, Ethos Easy) at 180°C for 10 min, according to an adaptation of EPA Method 3050B [29]. P, Ca, Mg, and Na concentrations were quantified by inductively coupled plasma optical emission spectrometry (ICP-OES, PerkinElmer Optima 7000 DV), whereas K was determined by flame photometry.

Leaf silicon concentration was determined according to the method proposed by [23]. Samples were subjected to alkaline digestion with sodium hydroxide (NaOH) and hydrogen peroxide (H_2O_2) in an autoclave and subsequently analyzed by spectrophotometry (NI 2000UV, Nova Instruments, Brazil) at 410 nm using ammonium molybdate as the complexing agent.

2.5 Yield

Fruit harvests were performed on June 17, 2022 and May 30, 2023, corresponding to the 2021/2022 and 2022/2023 seasons, respectively. Fruits were harvested at maturity stage 2, characterized by cream-yellow pulp color, according to the classification proposed by Filgueiras et al. (2000). This stage is recommended for mango harvest because it represents an appropriate point of physiological development and postharvest ripening potential. All fruits produced by plants in the usable area of each experimental plot were manually harvested, placed in plastic containers, and immediately weighed using a precision electronic balance. Production was expressed as kilograms per plant (kg plant^{-1}), calculated as the ratio between total fruit mass and the number of plants evaluated in each plot.

2.6 Statistical Analysis

Data were subjected to analysis of variance (ANOVA), and when a significant treatment effect was detected by the F test ($p \leq 0.05$), means were compared using Tukey's test at the 5% probability level ($p < 0.05$). All statistical analyses were performed using SISVAR software, version 5.6.

RESULTS

3.1 Gas Exchange

Stomatal conductance (gs) was the only gas-exchange variable affected by diatomaceous earth (DE) application during the first production cycle (Table 3). Values ranged from 0.160 mol H_2O m^{-2} s^{-1} in T2 to 0.120 mol H_2O m^{-2} s^{-1} in T5, corresponding to an approximately 24% reduction at the highest DE dose relative to the control. Intermediate treatments showed gs values between these extremes, indicating a tendency for stomatal conductance to decrease as the Si dose supplied by diatomaceous earth increased.

In the second production cycle, however, no differences among treatments were observed, indicating that the effect of Si application on stomatal conductance was restricted to the first evaluation cycle. In contrast, net CO_2 assimilation rate (A), transpiration rate (E), and chlorophyll a and b indices were not affected by diatomaceous earth application in either cycle (Table 3).

Table 3
Analysis of variance summary for net photosynthesis (A), stomatal conductance (gs), transpiration (E), and chlorophyll a (Chl a) and chlorophyll b (Chl b) indices in 'Palmer' mango leaves as affected by diatomaceous earth application strategies in the 2021–2022 and 2022–2023 cycles.

Treatment	A	*gs*	E	ICF*a*	ICF*b*
	µmol CO2 m-2 s-1	mol H2O m-2 s-1	mol H2O m-2 s-1		
2021–2022					
Valor 'F'	2,494ns	6,213**	1,413ns	0,831ns	0,368ns
T1	16,986	0,158a	4,333	41,00	12,40
T2	16,680	0,160a	4,521	40,36	13,46
T3	15,590	0,132ab	4,249	42,88	13,30
T4	16,158	0,140ab	4,835	42,86	13,58
T5	14,326	0,120b	4,201	37,82	12,54
DMS	2,8830	0,0297	0,9410	9,9486	3,9027
CV (%)	9,33	10,80	10,97	12,52	15,12
2022–2023					
Valor 'F'	0,671ns	0,495ns	1,413ns	2,172ns	1,196ns
T1	12,845	0,138	4,333	32,94	8,16
T2	14,183	0,147	4,521	32,28	8,72
T3	14,141	0,153	4,249	36,94	10,90
T4	13,886	0,137	4,835	36,82	10,32
T5	14,302	0,131	4,201	36,70	10,40
DMS	3,0735	0,1412	0,9410	6,6610	4,5983
CV (%)	11,71	19,42	10,97	10,01	25,04

ns: not significant by the F test ($p \leq 0.05$); means compared by Tukey's test at 5% probability; **: significant by the F test ($p \leq 0.01$); MSD: minimum significant difference; CV: coefficient of variation. T1 – control; T2–50 kg ha^{-1} DE broadcast; T3–50 kg ha^{-1} DE broadcast + 1% foliar DE; T4–100 kg ha^{-1} DE broadcast; T5–100 kg ha^{-1} DE broadcast + 2% foliar DE.

3.2 Leaf Macronutrient, Silicon, and Sodium Concentrations

Leaf macronutrient concentrations showed distinct responses to diatomaceous earth application as a Si source, varying according to production cycle and phenological stage (Table 4). N concentration was affected only at harvest in the 2021–2022 cycle, when the control showed the highest value (16.27 g kg^{-1}), whereas Si treatments reduced this concentration by 6.9–11.8%. P concentrations were not affected by treatments in any evaluation. For K, a significant effect was observed only during shoot maturation in the 2021–2022 cycle, with lower leaf concentrations in treatments receiving Si.

Table 4
Analysis of variance summary for leaf macronutrient, Si, and Na concentrations in 'Palmer' mango during shoot maturation and harvest as affected by diatomaceous earth application strategies in the 2021–2022 and 2022–2023 seasons.

Treatement	N	P	K	Ca	Mg	S	Si	Na
	---------- (g kg-1) ----------							
Branch maturation – 2021–2022								
Valor 'F'	0,691ns	0,969ns	10,543*	0,562ns	1,187ns	1,06ns	5,233*	3,499*
T1	16,37	1,47	14,67a	23,22	2,85	1,40	2,01a	0,102ab
T2	16,30	1,62	13,37ab	23,97	2,45	1,32	1,02b	0,123a
T3	15,92	1,45	10,32bc	24,10	2,70	1,30	1,07b	0,094ab
T4	15,45	1,55	8,32c	22,17	2,50	1,10	1,03b	0,081ab
T5	16,65	1,47	8,22c	21,02	2,42	1,32	1,14b	0,068b
DMS	2,52	0,33	4,07	7,81	0,60	0,49	0,83	0,051
CV (%)	6,93	9,66	16,47	15,12	10,37	16,94	29,51	24,39
Branch maturation – 2022–2023								
Valor 'F'	0,971ns	1,385ns	1,012ns	9,567*	17,386*	14,45*	4,187*	7,178*
T1	17,10	1,36	9,50	18,16b	1,90b	1,68a	2,07a	89,80b
T2	16,78	1,48	9,86	18,86b	1,80b	1,66a	1,83ab	100,42b
T3	16,64	1,48	9,38	20,30b	1,74b	1,74a	1,35ab	110,90b
T4	16,52	1,40	9,18	20,54b	1,86b	1,58a	1,17b	104,78b
T5	16,24	1,46	9,54	23,50a	2,32a	1,30b	1,29ab	141,50a
DMS	1,39	0,19	1,07	0,665	0,238	0,197	0,82	31,52
CV (%)	4,33	7,10	5,83	7,34	6,40	6,39	27,56	14,85
Harvest – 2021–2022								
Valor'F'	8,510*	2,400ns	3,801ns	4,005*	2,281ns	6,173*	18,714*	31,872*
T1	16,27a	1,32	8,45	33,87b	2,67	1,45ab	0,99b	0,186a
T2	15,05b	1,42	7,32	35,55ab	2,45	1,45ab	0,98b	0,160ab
T3	14,42ab	1,42	8,50	37,17a	2,32	1,60a	0,99b	0,185a
T4	14,35b	1,37	8,22	39,67a	2,45	1,20b	1,08a	0,131b
T5	15,12b	1,35	7,42	38,62a	2,55	1,25b	0,88b	0,1410b
DMS	1,078	0,370	4,130	5,247	0,389	0,490	0,680	0,0320
CV(%)	3,14	8,66	15,46	6,29	6,95	16,94	4,29	9,13
Harvest – 2022–2023								
Valor'F'	0,129ns	2,304ns	0,517ns	11,120*	1,163ns	2,270ns	16,615*	0,962ns
T1	15,72	1,30	6,20	22,58b	1,88	1,48	1,93a	0,113
T2	15,40	1,42	5,84	23,68b	1,80	1,53	1,51ab	0,121

Treatement	N	P	K	Ca	Mg	S	Si	Na
	---------- (g kg-1) ----------							
T3	15,40	1,36	5,78	25,10b	1,82	1,32	1,33b	0,126
T4	15,32	1,38	5,90	24,78b	1,86	1,38	1,51ab	0,114
T5	15,16	1,40	6,34	35,66a	2,02	1,45	1,52ab	0,143
DMS	2,462	0,131	1,473	6,821	0,347	0,197	0,52	0,054

ns: not significant by the F test ($p \leq 0.05$); means compared by Tukey's test at 5% probability; **: significant by the F test ($p \leq 0.01$); MSD: minimum significant difference; CV: coefficient of variation. T1 – control; T2–50 kg ha^{-1} DE broadcast; T3–50 kg ha^{-1} DE broadcast + 1% foliar DE; T4–100 kg ha^{-1} DE broadcast; T5–100 kg ha^{-1} DE broadcast + 2% foliar DE.

Si application increased leaf Ca concentrations, particularly in T5. During shoot maturation, a significant effect was observed only in the second cycle, with a maximum concentration of 23.50 g kg^{-1}. At harvest, T5 showed the highest Ca concentrations in both cycles, reaching 38.88 and 35.66 g kg^{-1} in 2021–2022 and 2022–2023, respectively. For Mg, an effect was observed only at harvest in the second cycle, also with higher values in T5.

Leaf S concentrations were affected only in specific evaluations. T5 showed the lowest S concentration during shoot maturation in 2022–2023 (1.30 g kg^{-1}), differing from the other treatments, and also the lowest value at harvest in 2021–2022 (1.25 g kg^{-1}).

Si application also affected leaf concentrations of the element itself. During shoot maturation, T1 showed the highest Si concentrations in both cycles (2.01 and 2.07 g kg^{-1}). At harvest, the highest concentration was observed in T3 in the first cycle (1.12 g kg^{-1}), whereas in the second cycle the highest value occurred in T1 (1.93 g kg^{-1}), without differing statistically from T2, T4, and T5.

Leaf Na concentrations were reduced by the highest Si dose. During shoot maturation in 2021–2022, T5 showed a 33.6% reduction relative to the control (0.068 and 0.102 g kg^{-1}, respectively). At harvest in the same cycle, the reduction reached 29.8%, maintaining the tendency toward lower Na concentrations in treatments receiving 100 kg ha^{-1} DE.

3.3 Yield

Diatomaceous earth application did not affect mango yield in either production cycle (Fig. 2). In 2021–2022, yield ranged from 35.70 t ha^{-1} (T3) to 39.20 t ha^{-1} (T2). In 2022–2023, no significant differences among treatments were observed, with yields ranging from 32.10 t ha^{-1} (T3) to 34.80 t ha^{-1} (T4).

DISCUSSION

Diatomaceous earth application as a Si source had limited effects on the physiology and yield of 'Palmer' mango trees grown under irrigated conditions in the Submiddle São Francisco Valley. Although it reduced stomatal conductance during the first production cycle, it did not alter net photosynthesis, transpiration, chlorophyll indices, or plant yield. Regarding nutritional status, the response depended on production cycle and phenological stage, with reductions in leaf K, S, and Na concentrations and increases in Ca and Mg. However, Si application did not consistently increase leaf Si concentrations, demonstrating the low Si accumulation capacity of 'Palmer' mango. Overall, under the evaluated edaphoclimatic conditions, characterized by low abiotic stress intensity, diatomaceous earth application mainly promoted physiological and nutritional adjustments without increasing yield. These results suggest that the agronomic benefits of this Si source may be more pronounced when the crop is subjected to more intense abiotic stress.

CONCLUSION

Diatomaceous earth application as a Si source had limited effects on the physiology and yield of ‘Palmer’ mango trees grown under irrigated conditions in the Submiddle São Francisco Valley. Although it reduced stomatal conductance during the first production cycle, it did not alter net photosynthesis, transpiration, chlorophyll indices, or plant yield. Regarding nutritional status, the response depended on production cycle and phenological stage, with reductions in leaf K, S, and Na concentrations and increases in Ca and Mg. However, Si application did not consistently increase leaf Si concentrations, demonstrating the low Si accumulation capacity of ‘Palmer’ mango. Overall, under the evaluated edaphoclimatic conditions, characterized by low abiotic stress intensity, diatomaceous earth application mainly promoted physiological and nutritional adjustments without increasing yield. These results suggest that the agronomic benefits of this Si source may be more pronounced when the crop is subjected to more intense abiotic stress.

Declarations

Declarations Financial or Non-Financial Interests The authors have no affiliations with any organization or entity with any financial interest or non-finan cial interest in the subject matter or materials discussed in this study.

Competing Interests

The authors declare that they have no competing interests

Author Contribution

B.S. contributed to the conceptualization, methodology, investigation, data collection, formal analysis, interpretation of the results, and writing of the original manuscript. J.B.L. contributed to the investigation, data collection, data analysis, and interpretation of the results. A.G.L.S., I.H.L.C., A.M.N.L., and A.C.R. contributed to the methodology, interpretation of the results, supervision, and critical revision of the manuscript. All authors reviewed, read, and approved the final version of the manuscript.

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Figures

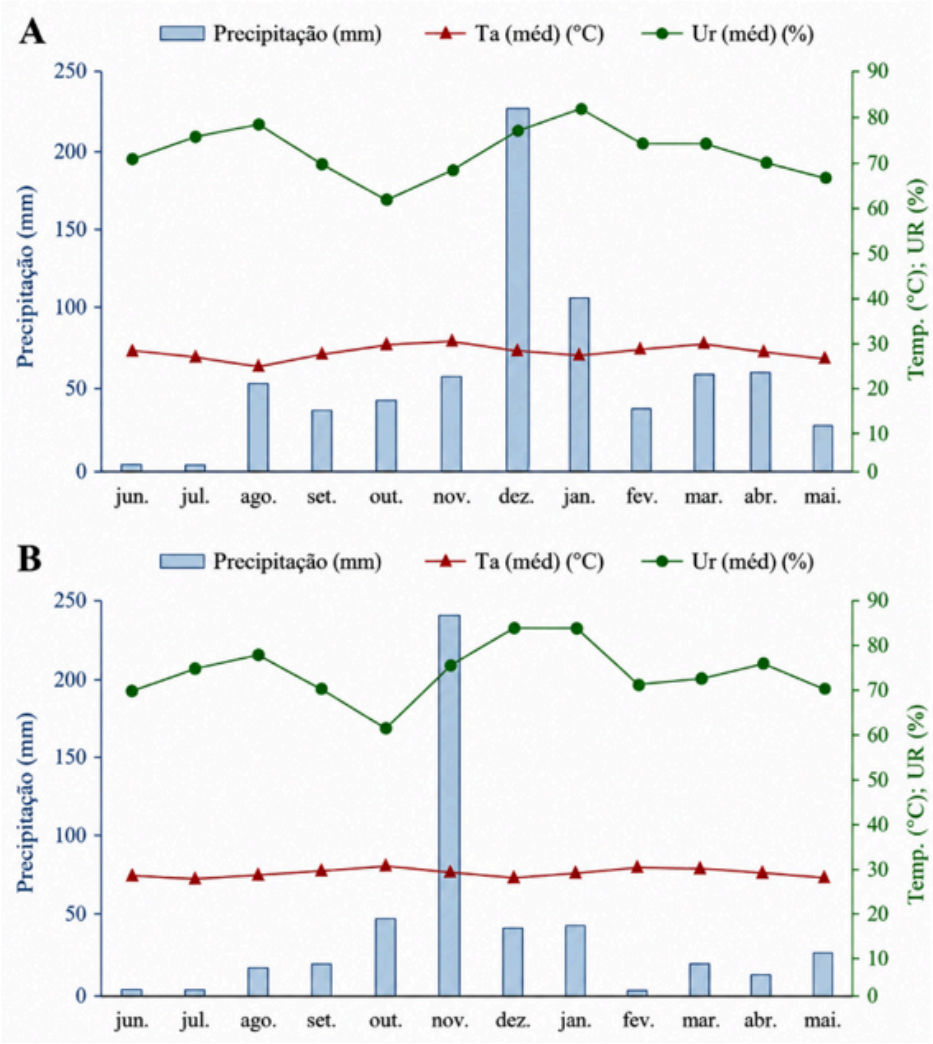


Figure 1

Rainfall, mean temperature, and relative air humidity recorded during the experiment in the 2021–2022 (A) and 2022–2023 (B) cycles.

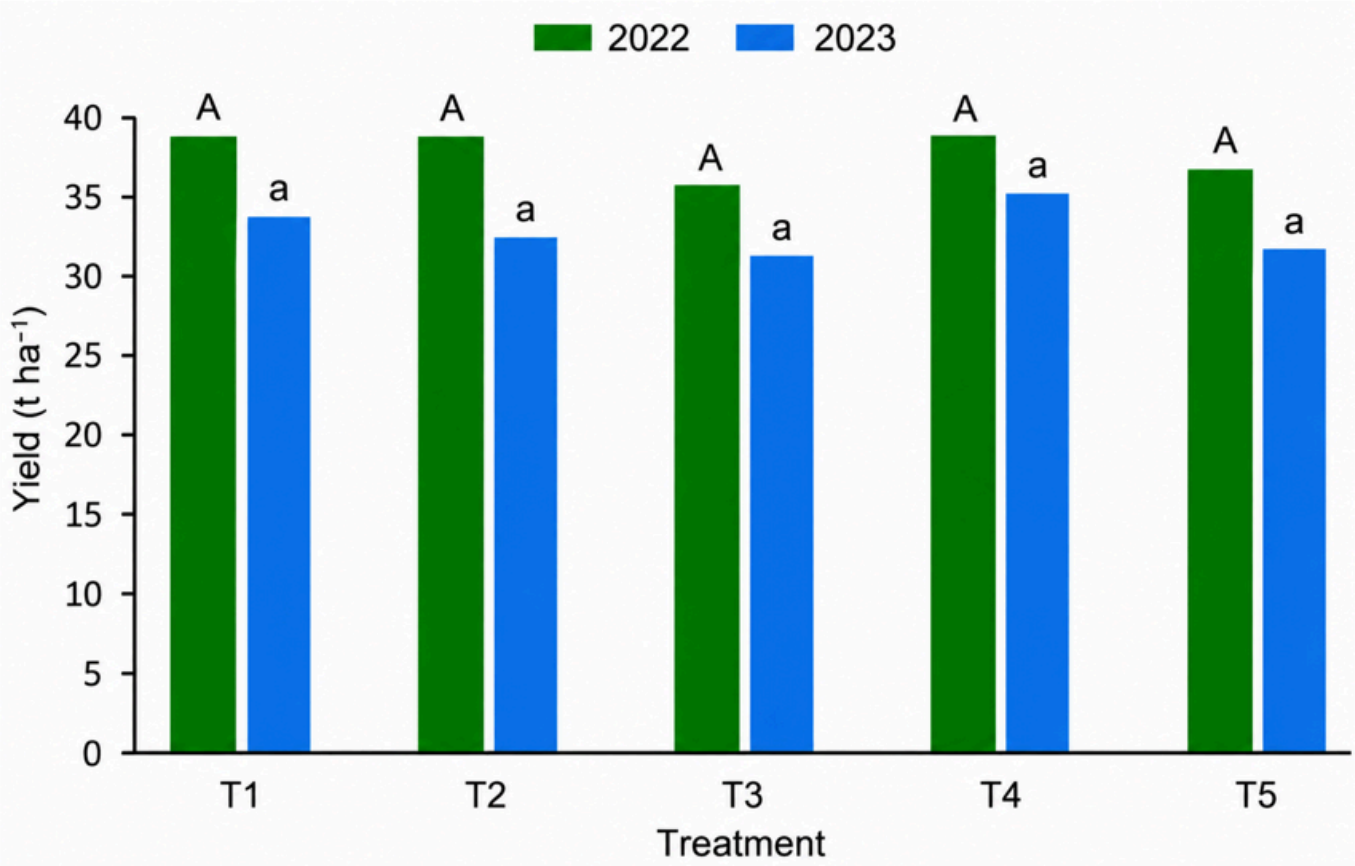


Figure 2

Yield of ‘Palmer’ mango trees as affected by diatomaceous earth application strategies as a silicon source during the 2021–2022 and 2022–2023 growing seasons.