CONTRIBUTION TO KNOWLEDGE ON THE CONTAMINATION OF BRS LEILA LETTUCE (L. SATIVA) BY LITHIUM CARBONATE (LI_2CO_3)

CONTRIBUIÇÃO AOS CONHECIMENTOS DA CONTAMINAÇÃO DE ALFACE BRS LEILA (L. SATIVA) POR CARBONATO DE LÍTIO (LI_2CO_3))

CONTRIBUCIÓN AL CONOCIMIENTO SOBRE LA CONTAMINACIÓN DE LA LECHUGA BRS LEILA (L. SATIVA) POR CARBONATO DE LITIO (LI_2CO_3)

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ABSTRACT
Considering the exponential growth use of lithium, as a metal reaching approximately 135,000 tons by 2024, due to its application in changing the energy matrix through its use in batteries of ubiquity in new technology equipment, and the fact that only about 3% of lithium is recycled. Considering that on former landfill sites, transformed by populations on the outskirts of cities, community gardens are established to grow a variety of vegetables and greens that supplement family income and daily diets. Considering the use of lithium as a mood stabilizer, antidepressant, and effective against violent and suicidal behavior. Considering that lithium has been used since the 1990s as a reducer in the percentage of crime, depression, and drug addiction. The preliminary research presented in this article was developed to contribute to scientific knowledge through a controlled laboratory experiment on lithium biofortification and its correlations with chemical elements with similar properties (Na, K, Mg, and Sr). BRS Leila lettuce (*L. sativa*) was cultivated in different samples (single and triple) contaminated with lithium carbonate (Li_2CO_3) at concentrations of 150 and 200 mol/L, at different irrigation times. It was concluded that Li correlates with other alkaline and alkaline earth elements, on leaves and roots of LS, and these associations can be developed to seek a more appropriate balance between the benefits and potential risks to health and the environment, converting what would be an environmental contamination into a benefit to the health of the population.

Keywords: *Lactuca sativa*. Lithium. Biofortification.

RESUMO
Considerando o elemento lítio, nos dias atuais, é um metal de crescimento exponencial de utilização, crescendo para a ordem de 135 mil toneladas em 2024, devido a sua aplicação na mudança da matriz energética, através o seu emprego em baterias, onipresença em

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equipamentos de novas tecnologias e que cerca de que apenas cerca de 3% do lítio é reciclado; considerando-se que em sítios de antigos lixões, transformados pelas populações de das periferias das cidades, são implantadas hortas comunitárias para cultivo de diversos legumes e hortaliças que completam a renda familiar e complementam a alimentação cotidiana; considerando a utilização de lítio como estabilizador de humor, antidepressivo e eficaz contra o comportamento violentos e suicida; considerando-se que o lítio utilizado desde a década de como redutor no seu percentual de crimes, depressão e dependência química; engendrou-se a pesquisa preliminarmente apresentada neste artigo, visando-se desta forma, contribuir com o saber científico, a partir de uma experiência controlada sobre a biofortificação em laboratório, sobre o lítio e suas correlações com elementos químicos de propriedades semelhantes (Na, K, Mg, Sr), cultivando-se a alface BRS Leila (*L. sativa*), em diferentes amostras (simples e triplas), contaminadas com carbonato de lítio (Li_2CO_3), em concentrações de 150 e 200 mol/L, em diferentes tempo de regas. Concluindo-se que o Li possui um comportamento correlacionado com os demais elementos alcalinos e alcalinos terrosos e estas associações podem ser desenvolvidas no sentido de se buscar por um equilíbrio mais adequado entre os benefícios e os possíveis riscos à saúde e ao ambiente, invertendo-se o que seria uma contaminação ambiental, em um benefício à saúde das populações.

Palavras-chave: *Lactuca sativa.* Lítio. Biofortificação.

RESUMEN

Considerando el uso actual del litio, un metal que experimenta un crecimiento exponencial, alcanzando aproximadamente 135.000 toneladas para 2024, debido a su aplicación en la transformación de la matriz energética mediante su uso en baterías, su ubicuidad en equipos de nueva tecnología y el hecho de que solo alrededor del 3% del litio se recicla; considerando que en antiguos vertederos, transformados por poblaciones en las afueras de las ciudades, se establecen huertos comunitarios para cultivar una variedad de vegetales y hortalizas que complementan los ingresos familiares y la dieta diaria; considerando el uso del litio como estabilizador del ánimo, antidepresivo y eficaz contra la conducta violenta y suicida; considerando que el litio se ha utilizado desde la década de 1990 como reductor de la tasa de delincuencia, depresión y drogadicción; la investigación preliminar que se presenta en este artículo se desarrolló para contribuir al conocimiento científico a través de un experimento de laboratorio controlado sobre la biofortificación con litio y sus correlaciones con elementos químicos con propiedades similares (Na, K, Mg, Sr). Se cultivó lechuga BRS Leila (*L. sativa*) en diferentes muestras (simples y triples) contaminadas con carbonato de litio (Li_2CO_3) en concentraciones de 150 y 200 mol/L, con diferentes tiempos de riego. Se concluyó que el litio se correlaciona con otros elementos alcalinos y alcalinotérreos, y que estas asociaciones pueden desarrollarse para lograr un equilibrio más adecuado entre los beneficios y los posibles riesgos para la salud y el medio ambiente, convirtiendo lo que de otro modo sería contaminación ambiental en un beneficio para la salud de la población.

Palabras clave: *Lactuca sativa*. Litio. Biofortificación.

1 INTRODUCTION

Lettuce is an upright, edible vegetable of the daisy family (Asteraceae), native from the Mediterranean to Siberia and, adapted perfectly in the tropics, occurs in different varieties, colors and is widely consumed in all parts of the globe.

A successful lettuce species is *Lactuca sativa (LC),* a member of the Compositae family of flowering plants, where about 27 million hectares are planted around the globe for this family of vegetables, developing best in full sun or partial shade, in organically rich, moist and well-drained soils. The ideal pH ranges from 6 to 6.7. The leaves can be harvested by removing them individually (2 to 3 inches long) or the entire plant, and can be harvested in around 70 sowing.

LS is a type of lettuce widely consumed in Brazil, in view of its ease of cultivation, in several locations in Brazil, especially on the outskirts of cities, in many places where household garbage dumps, various rubble, places generically called dumps, were installed transformed by the communities into vegetable gardens, with extensive cultivation of lettuce and other vegetables for ready consumption by the populations. For example, the Community of São Torquato, in Espírito Santo or the neighborhood of Morro Azul, on the outskirts of São Sebastião, the Federal District and many others.

Common are the statements of "*This here was a dump before, it was a space destined for garbage. People threw garbage here. After it was transformed into small flowerbeds, we managed to put an end to the dump." (*Vegetable garden on the outskirts of the Federal District replaces garbage with vegetables and fruits - CEUB News Agency), thus ratifying the need to engender research that will contribute to the scientific knowledge of the action of the chemical elements disseminated and present in these sites and that were possibly incorporated by these edible plants and later incorporated for those who use them in daily food.

Lithium (Li) is an alkali metal discovered in 1817 by Johann August Arfvedson, in studies of petalite, a mineral discovered and classified by José Bonifácio de Andrade e Silva, being the only Brazilian related to the discovery of a chemical element. It is the third element in Mendeleev's periodic table, and is located in column 1A, just above sodium, an element with very similar chemical properties and, in turn, above potassium. Like the other elements in its group, Li has a single valence electron, which is easily lost to form the LiN cation, which explains its low electronegativity. (Gill, 1989).

Also, in the periodic table, Li can be linked diagonally to its neighboring element, magnesium (Mg). The proximity of the values of the ionic radius Li (0.76 Angstrom), (0.76 Angstrom), Mg (0.72 Angstrom), Na (1.02 Angstrom) and K(1.038 Angstrom) following the laws of Goldschmidt/Pauling substitutions, following a sequence of ease of substitution, due to the proximity of ionic radii sizes, in Li-Mg-Na-K sequence. Other important points of the alkaline chemical elements, which engenders greater mobility and conduction of electric current in solution, following the same order of the chemical elements, are solubility, conductivity, solvation. It should be noted that the intrinsic characteristics of Li place it as one of the most important elements in the current times of the electronics industry, data transmission, energy storage and change of the energy obtained by combustion to photovoltaic, being one of the most important components in the green energy transition, through Li-ion batteries (Cruz *et al.*, 2025).

In addition to its use in the electronics industry, Li is an important component associated with lubricants. Among the main characteristics of lithium greases is its resistance to water and ease of working at high temperatures (up to 150ºC), in addition, it has a high degree of adhesion on metal surfaces and offers good performance in both high and low load applications. It can also be used in both high- and low-speed processes.

Li is also used in human health benefits, being present in drugs, in the predominant form of lithium carbonate, widely used for the treatment of bipolar disorders, being the agent that has the most therapeutic evidence of mental illnesses and reduction of suicides (Cruz *et al.,* 2022).

World Mine Productions & Reserve reported that in 2023, Li's known reserves were 26 million tons, with an output of about 130,000 tons. In 2024, there was an increase in production to about 135 thousand tons.

The volume of extraction and use of lithium has grown at an alarming rate in recent years, especially for the use of batteries. According to World Mine Productions & Reserves, from 2018 to 2023, there was a staggering 37% increase in the volume of ore mined. This trend is expected to continue, with a projected increase of 50% by 2030, with the start of new mineral ventures and the exploration of deposits outside the Australian axis. This rapid growth in extraction is a cause for serious concern.

Considering global production and the fact that only 3% to 5% of lithium batteries are recycled, it is estimated that about 12,800 tons will return to nature, with high probabilities of causing environmental problems, due to contamination. This fact will affect all countries, especially the least developed ones, where respect for the environment and the treatment of electronic waste are not regulated.

At this point it is related to lettuce, planted in gardens in old dumps, the element Li, from batteries, all types of equipment and human health. The behavior of lithium in lettuce is described by Shakoor *et al.,* (2023), where, this chemical element enters the root system through the continuous extracellular space of plants, including the cell walls and intercellular spaces, and is transported to the cells through the cell wall and can reach the vascular tissue and the specific regions of the cell wall found, in the endoderm, concentrating in the root cortex of the endoderm through transpiratory attraction, in the vicinity of high concentrations of Li and later concentrated in the leaves of the vegetable.

In view of the points described above, a research of controlled lettuce planting *(LS)* was engendered, sown in pots containing commercial vegetable soil, cultivated in a greenhouse, irrigated with lithium carbonate solutions with different concentrations and, then, collecting and analyzing the leaves and roots of the plants, with the objective of observing the bioaccumulation and substitution of Li relating to alkaline and alkaline earth elements (Na, Mg, K, Sr) and the metals Al, Fe, Mn, hoping that this study will be extended to existing gardens in places that have previously been dumps, seeking to contribute in this way, so that these results will contribute to the health of the populations.

2 METHODOLOGY

The experiment was carried out during the summer/autumn transition, in an external area without access to people. The local climate, according to the Thornthwaite climate classification is B1r'A, characterized as a humid environment, little or no water deficiency, megathermal (EP >1140mm), spring/summer and autumn/winter rainfall (SEI, 1997). During the entire period of plant development, air quality was measured and controlled using the JLDG JD-3002 equipment, recording CO2 values around 385ppm, TVOC close to 0.014 mg/m3, HCHO 0.0 mg/m3 and temperature around 25-26oC. All these data remained relatively constant.

The planting of *LS* was carried out in a substrate of 100% vegetable soil fertilized with cattle manure. A sample of about 100g was stored and analyzed at LePetro UFBA, to determine the elements Li, Ca, Mg, Al, Na and K, in addition to pH. In the Plasma laboratory of IGEO UFBA, lithium concentrate solutions were prepared. 1 liter of ultra-pure deionized water was used, adding lithium carbonate (Li_{2CO3}), in the ratio of 150 mol/L and 200mol/L. Li Carbonate was purchased from the company Exodus Científica and has the following composition on the label: Lithium carbonate PA - PM 73.89 g/mol.

The LS seeds , named BRS Leila, were acquired from the company Agrocinco, licensed by EMBRAPA. The seeds were visually selected and planted in 2L colorless plastic containers, filled with 1.5 kg of substrate each, perforated on the underside. The LS culture was arranged in a natural environment, in a greenhouse with a transparent plastic roof, which provided the cultivation and growth of the plants to indirect exposure to the sun's rays, receiving natural moisture, being, however, sheltered from the direct drips of the rains and the action of the wind. The experiment lasted about 70 consecutive days.

The following sampling experiments were carried out: i) Singular plant (1 individual) allocated individually in a pot; ii) Multiple plants (3 individuals), allocated in a pot and, iii) Reference white plants.

Weekly irrigation was carried out on the sample individuals (Single Plant and Multiple Plant), tripling the procedure and using the two concentrations of lithium carbonate solutions (Li2CO3). The white plant samples were irrigated with ultrapure deionized water. Around the seventieth day, the plants were developed, reaching the adult stage, with individualization roots/stem and leaves and an average size of 10cm, starting from the root. The collection process was carried out three biweekly and six weekly samplings.

Leaves with roots were harvested, washed with ultra-pure deionized water, individually, and replaced the water used. Each individual was weighed, measured, and separated leaf and root, packed in labeled airtight bags, and frozen. The frozen samples were lyophilized in the L108 equipment, Liobras brand, during a period of 24 hours. They were then individually sprayed in a shatterbox and sent for preparation for chemical analysis.

For the digestion of each sample, 1g of the pulverized sample was used, placed in Teflon Becker. The opening was made using 5ml of concentrated nitric acid of 65% P.A. Digestion was processed on an analog heating plate, at 90°C, in a laboratory cap, for four hours, being homogenized every hour.

After removing the plate and cooling it for about 1 hour in the chapel environment, 1ml of 30% hydrogen peroxide was added to each Becker-sample and left to process the digestion for a period of 2 hours on a heating plate, processing the homogenization of the sample every hour, using a glass rod. After cooling, the samples prepared for analysis were transferred to 15ml tubes, transparent and avoluted with ultrapure deionized water.

The samples were analyzed in the ICP-OES Thermoscientific model iCAP PRO of the Plasma Laboratory of the Institute of Geosciences of UFBA, using ultrapure argon gas. The following chemical elements were analyzed: Li, Na, K, Sr, Mg, Al, Fe, Mn, Co and Zn, whose means are shown in Table 1.

3 RESULTS

The analyses of the SL planting substrate showed the results pH of 6.0 and the completely absent Li content below 25mg/Kg. Na content of the order of 0.09cmol/dm3, K of the order of 0.15 cmol/dm3 Mg of the order of 0.36cmol/dm3, Ca of the order of 1.23cmol/dm^3 and Al <0.031cmol/dm3 were found. These chemical elements were analyzed following the

ST of Water and Waster, 2005. And from the calculation of the exchangeable capacity of cations and are bioavailable to the plant under development.

The results of the chemical analysis of the leaf and root samples of the LS cultivation experiment irrigated with lithium carbonate (Li2CO3), in several reasons, are presented in Table 1 (analytical results in Crelier annexes, unpublished). Figure 1 (A,B,C,D,E,F,G,H,I) presents the histograms of the chemical elements Li, Na, K, Mg, Ca, Sr, Al, Fe and Mn reciprocally, the calculated errors of the values of the analytical means are also traced. Figure 2 presents the *block-plot diagrams* of the results of the means of the analyses of the elements Li (A), Na (B), K (C), Mg (D), Ca (E), Sr (F), Al(G), Fe (H) and Mn (I). Figure 3 presents the binary diagrams of the results of the means of the analysis of the elements Li (A), K (B), Mg (C), Ca (D), Sr (E), Al(F), Fe (G) and Mn (H) in relation to the Na contents.

Table 2 presents the minimum, mean, median, standard deviation and maximum values obtained from the elements Li, Na, K, Mg, Ca, Sr, Al, Fe, Mn of the cultured SL samples. It is observed that the analyses of the elements Li, Na, Mg, Ca, Sr, Fe and Mn show low dispersion of the points, around the mean, which does not happen for the element K and for the Al in the set of roots 150 Li2CO3 30 days.

4 DISCUSSIONS

The set of histograms of the chemical elements analyzed, presented in figure 1, allows us to observe that the important effect of irrigation with lithium carbonate Li2CO3 and its different concentrations (200 mol/L and 150 mol/L). The comparison of the samples irrigated with ultra pure water with the samples irrigated with different concentrations, even in different irrigation periods, where the reference species (White) present very low or undetected levels of the elements Li, Na, K, Mg, Ca, Sr, Al, Fe, Mn, except for Na, which present low values, however, proving the absorption by the reference plants.

Observing the set of histograms in figure 1 (A,B,C,D,E,F,G,H,I) the effect of the Li2CO3 200 mol/L solution on the Li2CO3 150 mol/L solution is observed. Faith and Mn.

Regarding the watering period of Li2CO3 150 mol/L, the leaves watered for the period of 15 days present more varied concentrations in relation to the leaves watered for the period of 30 days for the elements Li, Na, K, Mg, Ca and Sr. The elements Al, Fe and Mn do not present important variations. Higher values than the average of Al and Fe were observed, which would be related to some type of contamination of the roots of the species analyzed.

Table 1

Mean of the chemical analysis of LS leaves and roots. (results in Crelier annexes, unpublished).

	Li2CO3	Read	In	K	Mg	Ca	Mr	Al	Fe	Mn
	mol/L	Ppm								
7sheet	200,00	0,047	2,66	21,77	1,37	2,50	0,25	0,44	0,13	0,04
leaf	200,00	0,040	3,30	26,07	1,80	3,11	0,28	0,11	0,06	0,05
10 sheet	200,00	0,036	4,76	38,37	2,10	4,43	0,45	0,17	0,11	0,07
9sheet	150,00	0,035	3,27	31,55	1,46	3,24	0,31	0,20	0,08	0,03
9sheet	150,00	0,035	3,27	31,55	1,46	3,24	0,31	0,20	0,08	0,03
15 sheet	150,00	0,032	6,17	45,84	7,09	16,15	1,80	0,23	0,13	0,22
16 sheet	150,00	0,031	5,78	48,88	3,20	7,90	0,66	0,14	0,09	0,06
21 sheet	150,00	0,023	5,37	47,00	3,43	6,42	0,99	0,21	0,13	0,06
22sheet	150,00	0,018	6,04	49,58	6,07	13,96	2,68	0,22	0,12	0,19
32sheet	150,00	0,018	4,92	29,51	2,38	6,99	1,43	0,47	0,12	0,05
34sheet	150,00	0,021	7,30	47,96	7,72	18,66	3,75	1,65	0,44	0,25
49sheet	150,00	0,032	7,11	31,00	3,37	8,68	0,85	0,56	0,21	0,06
50 sheets	150,00	0,042	7,37	40,39	3,99	10,20	0,93	0,95	0,26	0,11
51 sheet	150,00	0,031	7,12	28,37	2,62	12,76	0,70	0,38	0,12	0,05
66sheet	150,00	0,032	6,00	38,27	3,62	9,73	0,95	0,45	0,15	0,07
68sheet	150,00	0,038	7,22	43,74	3,26	9,40	0,99	1,02	0,26	0,04
31 root	150,00	0,028	5,43	17,52	2,30	3,92	1,52	3,80	1,22	0,04
33root	150,00	0,025	6,55	18,21	1,70	4,99	1,65	7,56	1,74	0,09
67root	150,00	0,037	4,07	10,53	1,48	3,02	0,75	2,28	0,70	0,02
root 30	150,00	0,051	3,67	9,89	1,54	2,79	0,62	6,43	1,51	0,03
White root	150,00	0,000	0,94	0,01	0,01	0,01	0,02	0,04	0,01	0,00
White sheet	150,00	0,000	0,80	0,01	0,00	0,02	0,00	0,02	0,01	0,00

(grey)	Plant irrigated 200 mol/L Li2CO3
(light blue)	Plant watered 150 mol/L Li2CO3 15 days
(light peach)	Plant watered 150 mol/L Li2CO3 15 days
(blue)	Root watered with 150 mol/L of Li2CO3 15 days
(orange)	Root watered with 150 mol/L of Li2CO3 30 days

Source: Authors, 2025

The set of box plot diagrams presented in figure 2 allows us to observe similar behaviors for the elements Li, Na and K have similar behaviors for the samples of leaves watered with 200 mol/L mol/L Li2CO3 and the roots watered with 150 mol/L and 30 days. On the other hand, leaves watered with 150 mol/L Li2CO3 for 15 days have similar absorptions of these elements.

Table 2

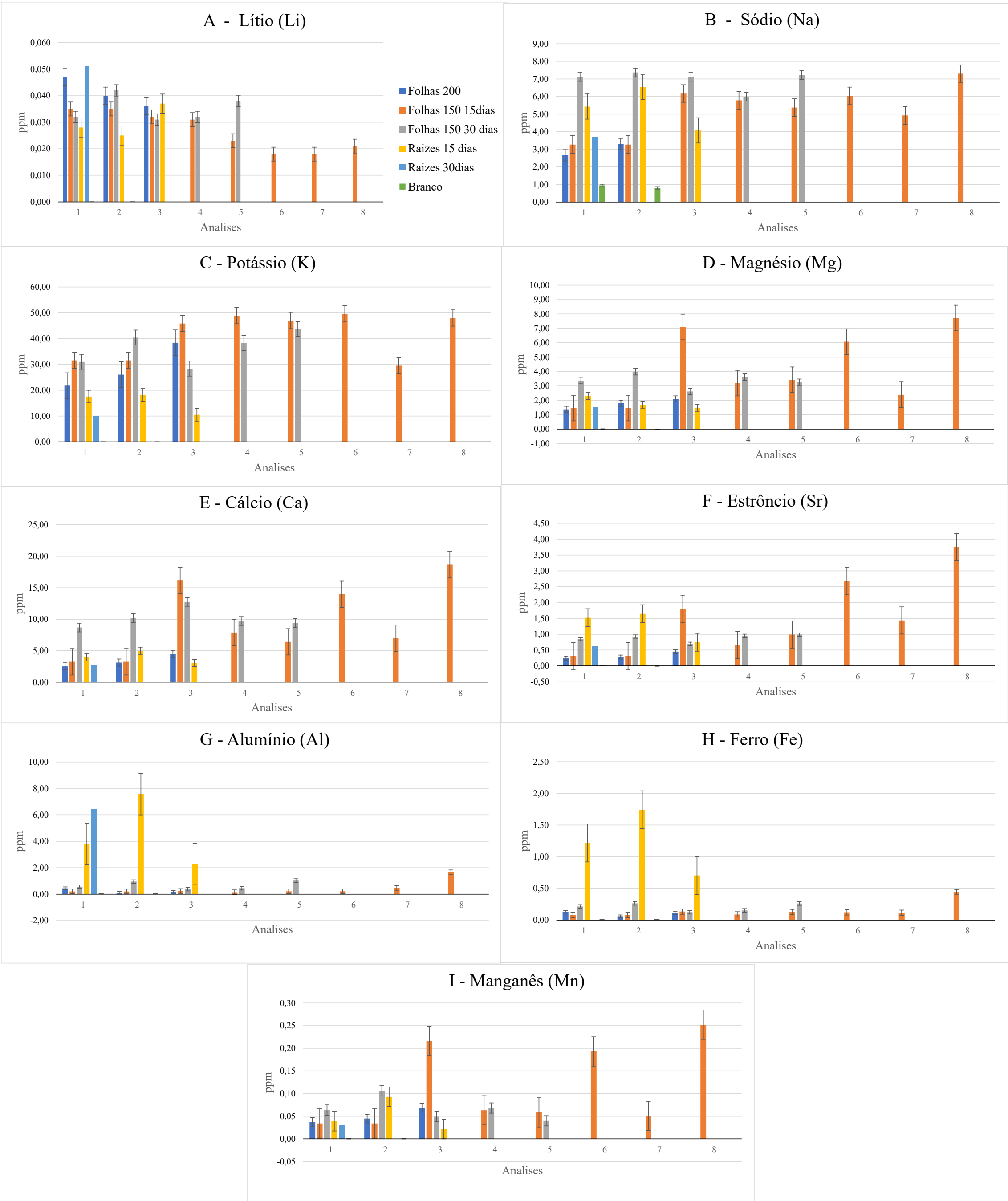
Minimum, mean, median, standard deviation and maximum calculated values of the values obtained from the elements Li, Na, K, Mg, Ca, Sr, Al, Fe, Mn of the cultured LS samples.

200mol/L Li2CO3 Sheets	Read	In	K	Mg	Ca	Mr	Al	Fe	Mn
									0,00
Minimum	0,04	2,66	21,77	1,37	2,50	0,25	0,11	0,06	0,04
Average	0,04	3,37	27,19	1,70	3,17	0,30	0,17	0,09	0,05
Median	0,04	3,30	26,07	1,80	3,11	0,28	0,17	0,11	0,05
Standard deviation	0,00	0,88	7,04	0,30	0,80	0,09	0,14	0,03	0,01
Maxim	0,05	4,76	38,37	2,10	4,43	0,45	0,44	0,13	0,07
Sheets 150mol/L Li2CO3 15 days									
Minimum	0,02	3,27	29,51	1,46	3,24	0,31	0,14	0,08	0,03
Average	0,02	4,88	39,63	2,83	6,50	0,74	0,24	0,11	0,06
Median	0,03	5,58	46,42	3,31	7,44	1,21	0,21	0,12	0,06
Standard deviation	0,01	1,32	8,31	2,35	5,53	1,14	0,47	0,11	0,09
Maxim	0,04	7,30	49,58	7,72	18,66	3,75	1,65	0,44	0,25
Sheets 150mol/L Li2CO3 30 days									
Minimum	0,03	6,00	28,37	2,62	8,68	0,70	0,38	0,12	0,04
Average	0,03	6,92	35,40	3,31	9,98	0,87	0,57	0,19	0,06
Median	0,03	7,12	38,27	3,37	9,73	0,93	0,56	0,21	0,06
Standard deviation	0,00	0,49	5,78	0,45	1,39	0,10	0,27	0,06	0,02
Maxim	0,04	7,37	43,74	3,99	12,76	0,99	1,02	0,26	0,11
Roots 150mol/L Li2CO3 15 days									
Minimum	0,03	4,07	10,53	1,48	3,02	0,75	2,28	0,70	0,02
Average	0,03	5,15	14,49	1,77	3,82	1,15	3,60	1,06	0,04
Median	0,03	5,43	17,52	1,70	3,92	1,52	3,80	1,22	0,04
Standard deviation	0,01	1,01	3,47	0,35	0,80	0,40	2,22	0,42	0,03
Maxim	0,04	6,55	18,21	2,30	4,99	1,65	7,56	1,74	0,09
Roots 150mol/L Li2CO3 30 days									
Minimum	0,05	3,67	9,89	1,54	2,79	0,62	6,43	1,51	0,03
Average	0,05	3,67	9,89	1,54	2,79	0,62	6,43	1,51	0,03
Median	0,05	3,67	9,89	1,54	2,79	0,62	6,43	1,51	0,03
Standard deviation	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Maxim	0,05	3,67	9,89	1,54	2,79	0,62	6,43	1,51	0,03
White									
Minimum	0,00	0,80	0,01	0,00	0,01	0,00	0,02	0,01	0,00
Average	0,00	0,86	0,01	0,00	0,02	0,00	0,03	0,01	0,00
Median	0,00	0,87	0,01	0,01	0,02	0,01	0,03	0,01	0,00
Standard deviation	0,00	0,07	0,00	0,01	0,00	0,01	0,01	0,00	0,00
Maxim	0,00	0,94	0,01	0,01	0,02	0,02	0,04	0,01	0,00

Source: Authors, 2025

Figure 1

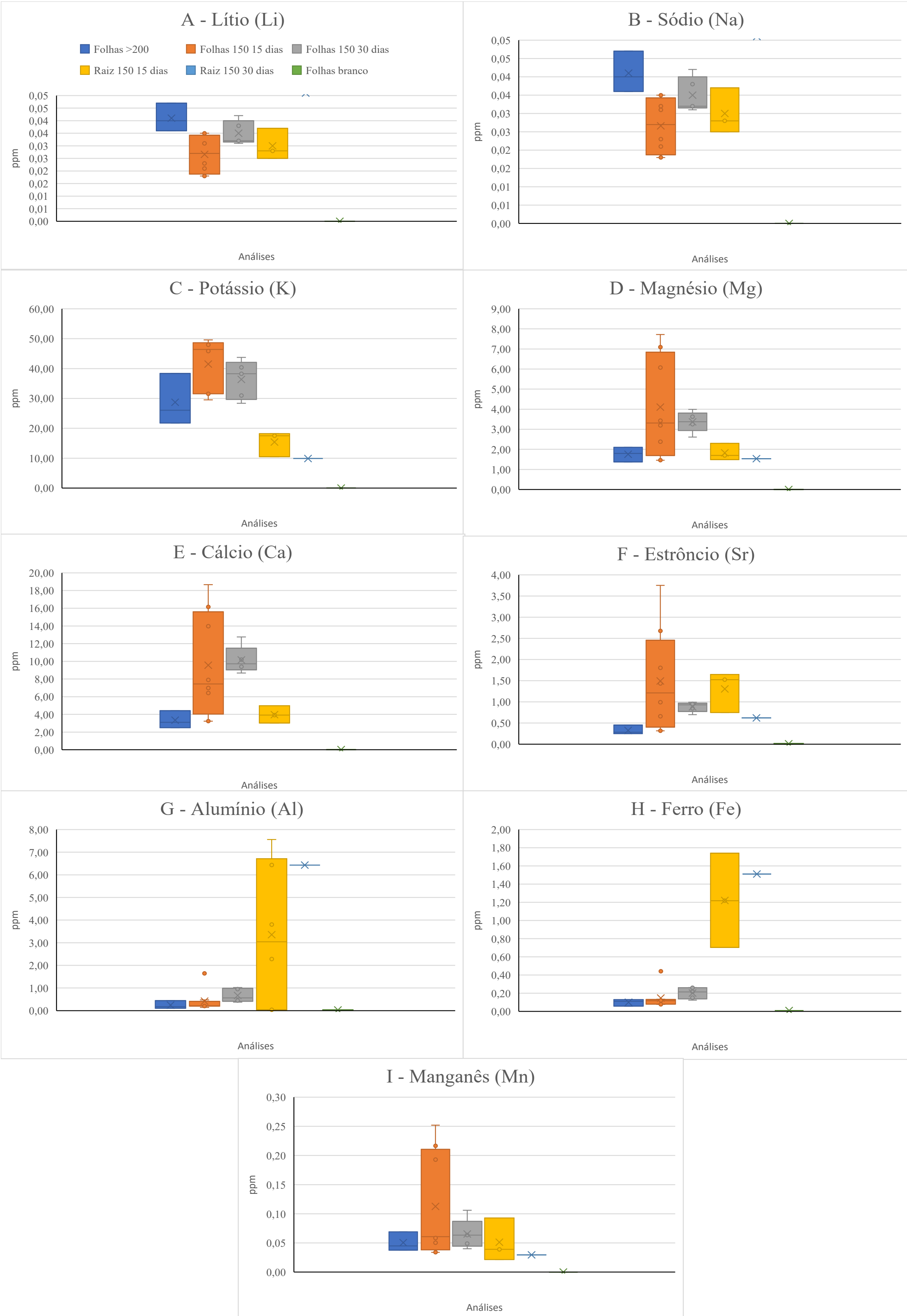
Histograms of the results of the means of the analyses of the elements Li (A), Na (B), K (C), Mg (D), Ca (E), Sr (F), Al(G), Fe (H) and Mn (I), with the calculated analytical error.



Source: Authors, 2025

Figure 2

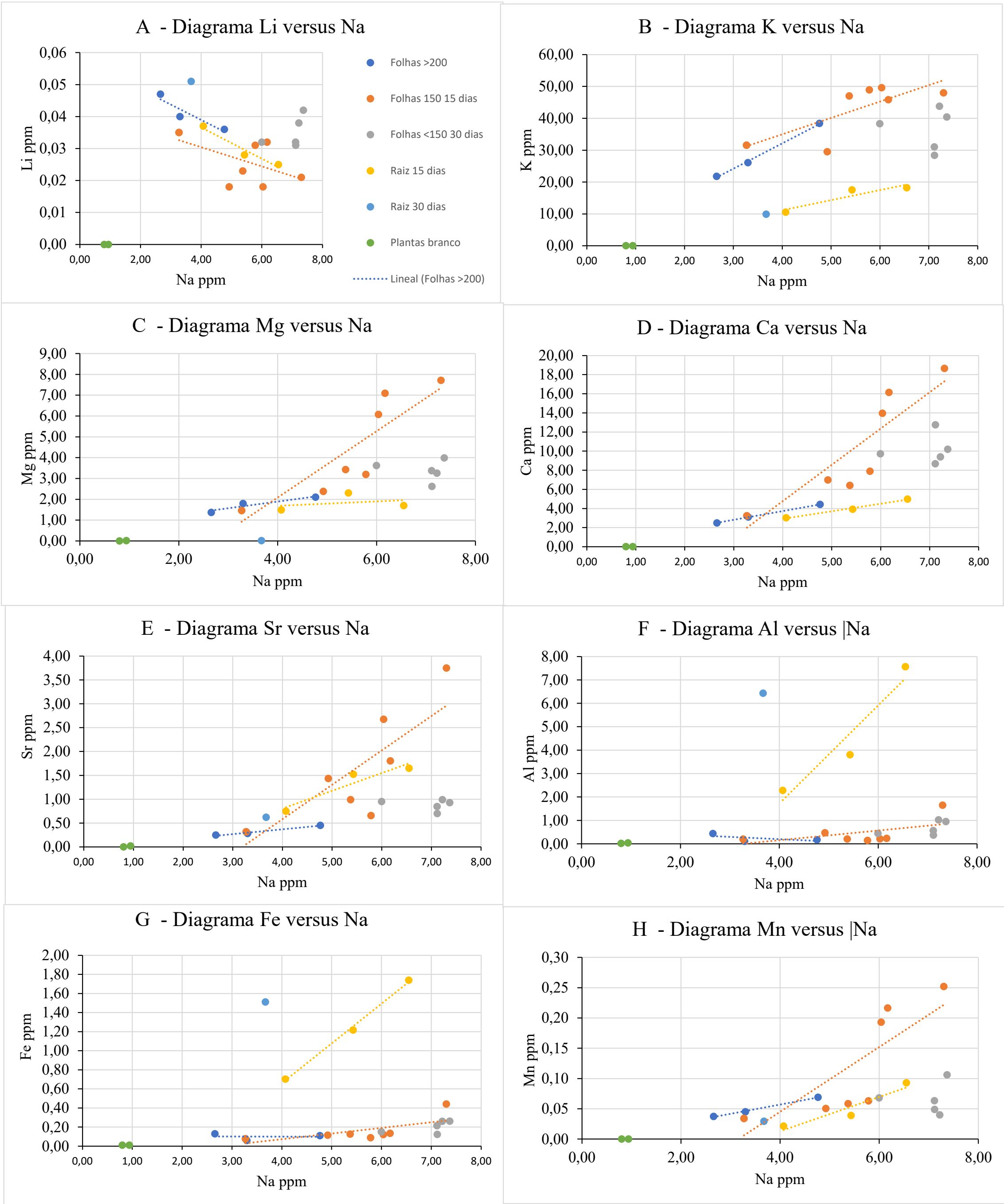
Block-plot diagrams of the results of the means of the analyses of the elements Li (A), Na (B), K (C), Mg (D), Ca (E), Sr (F), Al(G), Fe (H) and Mn (I),



Source: Authors, 2025

Figure 3

Binary diagrams of the results of the means of the analysis of the elements Li (A), K (B), Mg (C), Ca (D), Sr (E), Al(F), Fe (G) and Mn (H) in relation to the Na contents.



Source: Authors, 2025

The alkaline earthy elements Ca and Sr show greater absorption variations for the watered leaves: 150 mol/L Li2CO3 for 15 days. The metallic elements Al and Fe show great variations in the roots watered for 15 days and the Mn shows the greatest variation for the leaf samples watered by 150 mol/L Li2CO3 for 15 days.

With the exception of Li, the element Na is the one with the greatest geochemical mobility (Gill, 1989), in view of its chemical potential. Na is present in all samples of the LC experiment, even in plants irrigated only with pure water. For this reason, it was decided to choose this chemical element with reference and observe the behaviors of the other elements analyzed, i.e. Li, K, Mg, Ca, Sr, Al, Fe and Mn in relation to Na (Figure 3 - A,B,C,D,E,F,G,H) reciprocally.

The Li (Figure 3 A) shows the behavior of the Li in relation to the Na, it is verified that the way the Na grows there is a decrease in the Li. This element is further enriched in leaf specimens watered with mol/L Li2CO3, progressively decay relative to leaves watered with 150 mol/L Li2CO3 15 days and then to the roots. In the leaf samples watered 150 mol/L Li2CO3 30 days, the Li behaves in a lower trend than the others, however, internally in the set, the variations of analyzed contents do not present expressive correlations in relation to the Na. There is no correlation between Li and Na in the White samples.

The elements K, Mg, Ca and Sr, whose correlations with the element Na are shown in figures 3 - B, C, D and E show a positive correlation, starting in the representative samples of the roots and growing to the leaves watered at 200 mol/L Li2CO3 followed by leaves watered with 150 mol/L Li2CO3. It is important to note that the values of K and Sr tend to be very close, little dispersed, however it presents a tenuous correlation with Na.

The relationships of the metals Al, Fe and Mn in correlation with Na, shown in figures 3 – G, H and I, show the absence of correlation between these elements in the samples. The anomalous values of these elements, especially in the root samples, characterize contamination with the substrate and impregnation in the samples, where the residue was not completely removed, in the analytical preparation stages.

The behavior of Li in the SL samples cultured and analyzed follows what was cited by Shakoor *et al.*, 2023. The nutrients rich in this chemical element enrich from the roots, enriching towards the leaves, and variations in content in nutrient solutions are not important. According to Singh et al, 2019, in research mapping the distribution of Li elements and the distribution processes of this element in plant tissues, they proved that diffusion in plant leaves occurs through their veins (i.e., bundles of vascular tissue) and closer to the starting point of the Li-rich nutrient solution, thus ratifying the relationship of the higher levels found in the LS experiment with the 200 mol/L Li2CO3 solution.

The similarity of the behavior of the elements Mg, K, Ca and Sr and the evolution of Li in relation to these elements, can be understood by the similarities in their ionic radii and the weak coordination. There is an effective substitution of these elements throughout the experiment, which is denoted by the strong correlations, however one should not forget the possibility of contamination induced by products in inclusions and in cavities or structural voids, during the absorption phase of the metals, as explained by Shazat *et al.*, 2016.

Although not an essential mineral for plants, Li affects the growth and metabolism of certain plants, causing necrotic lesions (Kavanagh *et al.,* 2018). During the LC planting and watering experiment, this anomaly was not observed.

5 CONCLUSIONS

Developing experiments that bring together aspects of analytical and experimental geochemistry and relating them to biology always requires the improvement of the methodology, especially with regard to the care with the choice of seeds, the development of the plants, the substrate used, the place where the experiment will be developed and the choice of the contaminant that will be used. In the experiment described in this article, it became evident the need to repeat the experiment, based on the methodological development engendered and the need to use not only the contaminant Li2CO3, but also to include other solutions, such as LiCl or Li2SO4. Another very important point in the preparation of solutions is to observe the reliability of the contents present on the labels of these solutions. The greatest contribution of this research was the development of the methodology, following the scientific rigor, which will contribute to future evaluations developed in this research on the bioaccumulation of Li in lettuce and to mark the factors that influence this process.

The results obtained in this research, despite the specific restricted conditions, ratify the need for the development of government actions in the vicinity of dumps, where the local population takes advantage of the sites previously occupied by all types of waste, including e-waste, which are a source of Li, present in the batteries, which were discarded. The experiment proved that in places where Li is not present, it is not present in the leaves and roots.

On the other hand, the Li present in solutions charged from areas where the batteries were discarded, easily become compounds, mainly in the form of carbonates, in places with a pH around 6, as is the case of landfills, developing contaminating solutions.

As evidenced in this research, Li has a behavior correlated with the other alkaline and alkaline earth elements and these associations can be developed in order to seek a more appropriate balance between the benefits and possible risks to health and the environment.

Finally, Shakoor *et al.,* (2023) concluded that lithium has a significant positive impact on human health if consumed in correct concentrations, however, negative aspects are present when there are concentrations, absent or very high in the diet And with the maxim of Paracelsus, Swiss doctor, father of toxicology: the difference between medicine and poison is the dose.

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