

The effect of using *Azotobacter* spp and banana peels on the essential oil content of three basil varieties

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ABSTRACT

The current study, which was conducted in 2024 at the city of Al-hindia in Kerbala\ Iraq. sought to ascertain the effects of the bio fertilizer *Azotobacter* on the active parameters limonene, linalool, and **alpha-pinene** of three sweet basil plants (*Ocimum basilicum* L., *Ocimum basilicum* var. purple, and *Ocimum basilicum* var. *citriodorum*). with three replications and a factorial arrangement, the aforementioned experiment was set up using a Randomized Complete Block Design (RCBD). Two components were included in the study: banana peels (0, 100, 150, and 200 g L⁻¹) and *Azotobacter* (0, 25, 50, and 100 g bacteria/m²). The extract basil fine powder using a soxhlet apparatus was measured the active compounds by HPLC examination. The results indicate an increase in the volatile oil content of the effective compounds Limonine, Linalool and **alpha-pinene** when treated with banana peels at concentration 200 g L⁻¹ was (12.78, 23.28 and 0.215 mg.g⁻¹), for *O. basilicum* L. was (11.20, 23.28 and 0.2025 mg g⁻¹) for *O. basilicum* var. Purple was (9.97, 21.76 and 0.1925 mg g⁻¹) for *O. basilicum* var. *Citriodorum*. The study suggests choosing the variety *O. basilicum* L. for industrial or antiseptic uses due to its richness in limonene, while the *var. purple* and *citriodorum* varieties can be directed towards medicinal and aromatic uses due to their content of linalool and **alpha-pinene**.

Keywords: Essential oils, basil, Azoobacteria, banana peels.

1.Introduction

Basil *Ocimum* spp., one of the most important aromatic and medicinal plants in the Lamiaceae family, is notable for its high genetic diversity and profusion of beneficial secondary compounds, such as flavonoids, phenols, and essential oils, which add to its expanding medicinal and economic significance [1]. To categorize, enhance genetically, and broaden organic farming, a comprehensive study is necessary to determine the physiological traits and genetic relationships among the various species and varieties that make up this genus, these species and varieties differ from one another in terms of morphological traits, chemical composition, and response to agricultural treatments[2], due to their detrimental effects on the environment and human health, intense chemical fertilizers are becoming less and less necessary as the world moves toward sustainable agriculture [3]. In this regard, one of the most significant contemporary agricultural techniques is bio-fertilization with *Azotobacter* bacteria *Azotobacter* spp., which enhance plant growth and stress tolerance, produce natural growth regulators like auxins and gibberellins, and aid in the biological fixation of atmospheric nitrogen[4]. Moreover, organic fertilization with rich plant residues, like banana peels, is a promising source of macro- and nutrients-micro, especially potassium, and helps to improve the physical and chemical characteristics of soil as well as its biological activity[5,6]. However, given the lack of genetic information on many regional variants, managing genetic resources necessitates a comprehensive understanding of the genetic variability among basil variations. The molecular analysis markers such as RAPD, ISSR, and SRAP are considered to be useful tools for constructing the chemical similarity tree and figuring out the genetic link between kinds since these highly variable markers aid in revealing the degree of genetic diversity within the same genus[7]. Additionally, integrating physiological criteria with genetic analysis broadens our understanding of the interactions between biological response to environmental stimuli and genetic composition [8]. This work is aimed to Determine the importance of using *Azotobacter* spp and banana peels in the essential oil content of three basil varieties.

2.Materials and Methods

The current study, which was conducted in 2024 at the city of Alhindia in Kerbala, Iraq, sought to ascertain the effects of the biofertilizer *Azotobacter* on the active parameters limonene,

linalool, and pinene of three sweet basil plants *O. basilicum* L., *O. basilicum* var. purple, and *O. basilicum* var. *citriodorum*. with three replications and a factorial arrangement, the aforementioned experiment was set up using a Randomized Complete Block Design (RCBD). *Azotobacter* 0, 25, 50, and 100 g bacteria/m² was the first factor in the study, while banana peels combined with soil (0, 100, 150, and 200 g L⁻¹) was the second. After combining the basil seeds with fertilizers-bio, they were planted [9]. The blended soil samples from Kerbala city were put in plastic pots measuring 32 cm in diameter and 50 cm in height, each of which could store 12 kg of soil. 50 sweet basil seeds were planted in plastic pots filled with soil on March 22, 2024, 3 cm deep in each pot. the soil analysis test was conducted before planting and fertilization by taking five random samples from the prepared field soil from different locations and at a depth ranging from 0-30 cm. the samples were mixed homogeneously, exposed to sunlight for 24 hours, ground, and then sieved with a sieve with 2mm openings for analysis in the soil analysis laboratory at Kerbala University, as shown in table (1). *Azotobacter* was used for bacterial inoculation, which was carried out all at once throughout the growing season. a 1-centimeter incision was made near the rhizosphere region, and then bacterial inoculation was applied subsequently according to [10].

Table. 1. Chemical Properties of Soil.

Chemical Properties	Values	Units
pH	7.60	-----
Ca	8.02	m/m L ⁻¹
HCO ₃	0.43	m/m L ⁻¹
Na	3.64	m/m L ⁻¹
S	3.03	m/m L ⁻¹
NH ₄ N	25.38	mg /kg ⁻¹
Mg	1.99	m/m L ⁻¹
K	2.67	m/m L ⁻¹
N ⁺	1.54	m/m L ⁻¹
Soil texture	mixture (clay sandy)	

Measure the active ingredients

Method of extraction: using a soxhlet apparatus, 50 g of powdered basil fins were placed in a thimble and extracted for 24 hours with 200 mL of 75% ether in a 1000 mL round flask. the extract was evaporated at 45 °C using a revolving evaporation apparatus [11]. Limonene, linalool, and pinene ($\text{mg}\cdot\text{g}^{-1}$) identification compounds by HPLC the ministry of science and technology in Baghdad using the C18-RP 25 cm \times 4.6 mm column. ID (pore size of 5.0 m) and stored at ambient temperature. With a detection wavelength of 250 nm, the mobile phase consisted of isocratic water and tri flour acetic acid (TFA):acetonitrile (65:35) adjusted to pH 3.0–3.5 at a flow rate of 1.0 mL/min the sample's concentration was computed as follows: a sample's concentration is equal to its area divided by the area of the standard X dilution factor [12,13].

Statistical Analysis

Three replications and a randomized complete block design with factorial layout were used to examine all of the recorded data. for comparison and mean separation, the least significant difference (LSD0.05) test was also employed [14].

3. Results

The results showed at table (2) that the interaction between *Azotobacter* and banana peel had a significant effect at the (LSD 0.05) level on the limonene content in all studied basil varieties *O. basilicum* L., *O. basilicum* var. purple, *O. basilicum* var. *citriodorum*. in the regular variety *O. basilicum* L., the limonene content gradually increased with the increase in (banana peel 200 g L⁻¹ concentration and the presence of *Azotobacter* 100 g bacteria/m², the highest value (14.87 mg g⁻¹) while the lowest value (6.56 mg g⁻¹). the purple variety *O. basilicum* var. purple increased with the increase in interaction (banana peel 200 g L⁻¹ concentration and the presence of *Azotobacter* 100 g bacteria/m², the highest value (12.73 mg g⁻¹) while the lowest value (5.64 mg g⁻¹). as for the limonene variety *O. basilicum* var. *citriodorum*, with the increase in interaction (banana peel 200 g L⁻¹ concentration and the presence of *Azotobacter* 100 g bacteria/m², the highest value (11.64 mg g⁻¹) while the lowest value (4.76 mg g⁻¹). The comparison between the varieties showed that the regular basil variety excelled in limonene content, followed by the purple and then the limonene variety.

Table 2. The effect of *Azotobacter* and banana peels in the presence of limonene mg g⁻¹ of different basil varieties.

	Banana peels g L ⁻¹	<i>Azotobacter</i> g.bacteria.m ²					
		0	25	50	100	Mean	
<i>O.basilicum</i> L.	0	6.56	7.86	8.94	9.45	8.2025	LSD (0.05) for interaction=1.95 Banana peels=1.87 <i>Azotobacter</i> =1.74
	100	7.85	8.75	9.56	10.63	9.1975	
	150	9.75	9.75	10.36	11.74	12.63	
	200	10.76	11.74	13.74	14.87	12.78	
	Mean	8.73	9.525	10.50	11.6725		
<i>O. basilicum</i> var. purple	0	5.64	6.85	7.75	8.45	7.1725	LSD (0.05) for interaction= 1.67 Banana peels=1.83 <i>Azotobacter</i> =1.74
	100	6.84	7.94	8.45	9.37	8.15	
	150	8.56	9.56	10.47	11.64	10.06	
	200	9.56	10.74	11.76	12.73	11.20	
	Mean	7.65	8.77	9.61	10.55		
<i>O. basilicum</i> var. citriodorum	0	4.76	5.87	6.76	7.43	6.21	LSD (0.05) for interaction= 1.88 Banana peels=1.74 <i>Azotobacter</i> =1.57
	100	5.75	6.45	7.87	8.95	7.255	
	150	6.47	7.45	9.56	10.75	8.5575	
	200	7.65	8.84	10.74	11.64	9.97	
	Mean	6.16	7.15	8.7325	9.69		

Based to results table (3) that the interaction between *Azotobacter* and banana peel had a significant effect at the (LSD 0.05) level on the linalool content in all studied basil varieties *O. basilicum* L., *O. basilicum* var. purple, *O. basilicum* var. citriodorum. in the regular variety *O. basilicum* L., the linalool content gradually increased with the increase in (banana peel 200 g L⁻¹

concentration and the presence of *Azotobacter* 100g bacteria/m², the highest value (26.87 mg g⁻¹) while the lowest value (19.76 mg g⁻¹). The purple variety *O. basilicum* var. purple increased with the increase in interaction banana peel 200 g L⁻¹ concentration and the presence of *Azotobacter* 100 g bacteria/m², the highest value (23.13 mg g⁻¹) while the lowest value (18.76 mg g⁻¹). As for the linalool variety *O. basilicum* var. *citriodorum*, with the increase in interaction (banana peel 200 g L⁻¹ concentration and the presence of *Azotobacter* 100 g bacteria/m², the highest value (23.87 mg g⁻¹) while the lowest value (16.65 mg g⁻¹). General trends indicate that the increased concentration of banana peels and the presence of *Azotobacter* together led to a significant and consistent increase in linalool accumulation compared to the individual treatments or the control, reflecting a positive synergistic effect between the two sources in enhancing the formation of secondary aromatic compounds.

Table 3. The effect of *Azotobacter* and banana peels in the presence of linalool mg g⁻¹ different basil varieties.

	Banana peels g L ⁻¹	<i>Azotobacter</i> g.bacteria.m ²				Mean	
		0	25	50	100		
<i>O. basilicum</i> L.	0	19.76	20.65	21.73	22.65	21.1975	LSD (0.05) for interaction= 1.85 Banana peels=1.77 <i>Azotobacter</i> =1.57
	100	20.45	21.74	22.74	23.86	22.1975	
	150	21.65	22.75	24.75	25.86	23.75	
	200	22.76	24.65	25.75	26.87	25.01	
	Mean	21.11	22.4725	23.99	24.81		
<i>O. basilicum</i> var. purple	0	18.76	19.65	20.20	20.93	19.89	LSD (0.05) for interaction= 1.85 Banana peels=1.73 <i>Azotobacter</i> =1.38
	100	19.65	20.76	21.84	22.87	21.28	
	150	20.65	21.65	22.75	23.86	22.43	
	200	21.76	22.75	23.76	24.86	23.28	
	Mean	20.21	21.20	22.1375	23.13		

<i>O. basilicum</i> var. <i>citriodorum</i>		0	25	50	100	Mean	LSD (0.05) for interaction= 1.67 Banana peels=1.43 <i>Azotobacter</i> =1.54
	0	16.65	17.65	19.76	20.65	18.68	
	100	17.65	18.75	20.45	21.75	19.65	
	150	18.54	19.65	21.76	22.76	20.63	
	200	19.76	20.54	22.86	23.87	21.76	
	Mean	18.15	19.15	21.46	22.26		

The results in table 4 that the interaction between *Azotobacter* and banana peel had a significant effect at the (LSD 0.05) level on the **alpha-pinene** content in all studied basil varieties *O. basilicum* L., *O. basilicum* var. purple, *O. basilicum* var. *citriodorum*. In the regular variety *O. basilicum* L., the **alpha-pinene** content gradually increased with the increase in banana peel 200 g L⁻¹ concentration and the presence of *Azotobacter* 100 g bacteria/m², the highest value (0.23 mg g⁻¹) while the lowest value (0.15 mg g⁻¹). The purple variety *O. basilicum* var. purple increased with the increase in interaction banana peel 200 g L⁻¹ concentration and the presence of *Azotobacter* 100 g bacteria/m², the highest value (0.22 mg g⁻¹) while the lowest value (0.15 mg g⁻¹). As for the **alpha-pinene** variety *O. basilicum* var. *citriodorum*, with the increase in interaction (banana peel 200 g L⁻¹ concentration and the presence of *Azotobacter* 100 g bacteria/m², the highest value (0.21 mg g⁻¹) while the lowest value (0.14 mg g⁻¹).

Table 4. The effect of *Azotobacter* and banana peels in the presence alpha-pinene mg g⁻¹ of different basil varieties.

	Panana peels g L⁻¹	<i>Azotobacter</i> g.bacteria.m²				Mean	
		0	25	50	100		
<i>O. basilicum</i> L.		0.15	0.16	0.17	0.18	0.17	LSD (0.05) for interaction=1.85 Panana peels=1.74 <i>Azotobacter</i> =1.48
	0	0.15	0.16	0.17	0.18	0.17	
	100	0.17	0.18	0.19	0.20	0.19	
	150	0.19	0.20	0.21	0.22	0.205	
	200	0.20	0.21	0.22	0.23	0.215	
	Mean	0.18.	0.1875	0.1975	0.2075		

<i>O. basilicum</i> var. purple		0	25	50	100	Mean	LSD (0.05) for interaction= 1.64 Panana peels=1.54 <i>Azotobacter</i> =1.37
	0	0.15	0.16	0.17	0.18	0.165	
	100	0.16	0.17	0.18	0.19	0.175	
	150	0.17	0.18	0.19	0.21	0.1875	
	200	0.19	0.20	0.21	0.22	0.2025	
	Mean	0.1675	0.175	0.1875	0.20		
<i>O. basilicum</i> var. citriodorum		0	25	50	100	Mean	LSD (0.05) for interaction= 2.54 Panana peels=1.85 <i>Azotobacter</i> =1.75
	0	0.14	0.15	0.16	0.18	0.1575	
	100	0.15	0.17	0.18	0.19	0.1725	
	150	0.16	0.18	0.19	0.20	0.1825	
	200	0.17	0.19	0.20	0.21	0.1925	
	Mean	0.155	0.1725	0.1825	0.195		

4. Discussion

The results showed that the use of *Azotobacter* in combination with banana peels led to a significant increase in the content of the main aromatic compounds (limonene, linalool and alpha-pinene) in all studied basil varieties, compared to the control treatments or the individual treatments. This increase indicates the presence of a synergistic effect between biofertilizer and organic extracts in activating the secondary metabolism processes responsible for producing volatile oils [15,16]. The positive role of *Azotobacter* is attributed to its ability to fix atmospheric nitrogen and secrete growth-promoting compounds such as auxins, gibberellins, and vitamins, in addition to improving the absorption of mineral elements. These factors contribute to enhancing the efficiency of photosynthesis and increasing the abundance of carbon products that enter the terpenoid pathways responsible for the formation of compounds such as limonene, linalool, and alpha-pinene [17]. As for banana peels, they are a rich source of potassium, phenols, and organic acids, which enhance metabolism and activate the enzymes responsible for synthesizing aromatic compounds. Additionally, they play a role in improving the plant's water content and stimulating intermediary metabolism, leading to an increase in the accumulation of volatile oils [18,19]. The results show that the highest limonene content was achieved in the regular variety *O. basilicum*

L. When treated with (*Azotobacter* 100 g bacteria/m² + banana peels 200 g/L⁻¹), the value reached 14.87, while the purple and lemon varieties recorded lower values (12.73 and 11.64 respectively)[20]. This indicates that the genetic variation between the varieties plays an important role in determining the efficiency of the biological response, as the normal variety has a greater ability to direct metabolism toward the production of monoterpenes compared to the colored or lemon varieties, which metabolically focus on other compounds such as anthocyanin or citral [21]. Regarding linalool, it became clear that its increase was consistent with the rising concentration of banana peels and the presence of *Azotobacter*, reaching the highest values in the regular variety (26.87 mg g⁻¹), followed by the purple (24.86 mg g⁻¹), and then the lemon (23.87 mg g⁻¹). these results are consistent with what [22]. That biotic treatments stimulate the accumulation of volatile oils by enhancing enzymatic activity in the mevalonate pathway. As for alpha-pinene, although its values were relatively lower than the other two compounds, it showed a similar trend in terms of positive response to the treatments, as its concentration gradually increased with the higher levels of banana peels and *Azotobacter*, confirming that all terpenoid compounds are affected by the nutritional and physiological improvement provided by these treatments[23]. These results indicate that the combination of *Azotobacter* and organic fertilizers banana peel can be relied upon as an effective approach to improving the quality of essential oils in medicinal and aromatic plants, thru mechanisms that include: activation of carbon and nitrogen metabolism, biochemical synthesis enzyme stimulation for terpenes, and improving the nutritional and water balance of the plant [24]. These results are consistent with previous studies such as[25]. Which showed that bio fertilization and organic fertilization contribute to increasing the volatile oil content in basil and medicinal herbs.

Conclusion

The results show that organic fertilization using banana peels and bio-fertilization with *Azotobacter* are effective ways to boost the quantity of alpha-pinene chemicals in basil varieties, especially *O. basilicum* L. this interaction between the biological and organic sources boosts the biochemical output, increases the economic and medicinal value of basil, and supports the shift to sustainable organic farming.

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References

1. Al-Yassiry, A. S., Aljenaby, H. K. A., Al-Masoody, I. H., & Al-Ibrahemi, N. (2024). Biofertilizers effects on the active compounds of sweet basil (*Ocimum basilicum* L.). *SABRAO Journal of Breeding and Genetics*, 56(1), pp. 425–432. <https://doi.org/10.54910/sabrao2024.56.1.3>
2. Al-Ibrahemi, N., Al-Asadi, Q. T. H. Y., Hassan, S. F., Hamid, B. A., & Jawad, N. N. (2024). Response of flax (*Linum usitatissimum*) to nano-NPK and EMG-1 in growth, oil content, and active compounds. *SABRAO Journal of Breeding and Genetics*, 56(6), pp. 2481–2487. <https://doi.org/10.54910/sabrao2024.56.6.29>
3. Alakashy, Z. H., & Al-Bedairi, N. (2020a). Growth and yield response of three *Ocimum basilicum* L. varieties to different nitrogen sources. *Plant Archives*, 20(1), pp.398–401.
4. Al-Masoodi, N. H., Al-Ibrahemi, N., Abdulammar, S. H., & Al-Yassiry, A. S. (2025). Fenugreek (*Trigonella graecum* L.) response to *Azotobacter* and orange peels in metabolism, growth, and yield traits. *SABRAO Journal of Breeding and Genetics*, 57(1), pp.311–318.
5. Hariyono, M., Mulyono, & Ayunin, I. Q. (2021). Effectiveness of banana peel-based liquid organic fertilizer application as potassium source for eggplant (*Solanum melongena* L.) growth and yield. *IOP Conference Series: Earth and Environmental Science*, 752, pp. 012022. <https://doi.org/10.1088/1755-1315/752/1/012022>.
6. Aliyu, M., Abdulmalik, Z., Bako, Z. M., Jega, R. M., & Kareem, W. (2024). Organic fertilizer production using banana peel, eggshells, and yeast: Effects on *Amaranthus* growth. *FUDMA Journal of Science*, 8(6), pp. 562–567. <https://doi.org/10.33003/fjs-2024-0806-3022>.
7. Zuil, S. G., Izquierdo, N. G., Luján, J., Cantarero, M., & Aguirrezábal, L. A. N. (2012). Oil quality of corn and soybean genotypes with increased oleic acid percentage as affected by intercepted solar radiation and temperature. *Field Crops Research*, 127, pp. 203–214.

8. Yu, R. H., Wang, Y. L., Sun, Y. S., & Liu, B. L. (2012). Analysis of genetic distance by SSR in waxy maize. *Genetics and Molecular Research*, 11(1), pp. 254–260.
9. Alakashy, Z. H., & Al-Bedairi, N. (2020b). Effect of three varieties of basil and the nitrogen source on essential oil contents. *European Journal of Agricultural Science*, 12(1), pp. 1–6.
10. Hussain, H. A., Thabit, H. M., Aljenaby, H. K. A., & Fadil, N. M. (2023). Response of total phenol and chemical qualities for *Helianthus annuus* L. to roselle extract and phenol spraying. *IOP Conference Series: Earth and Environmental Science*, 1215(1), p. 011008. <https://doi.org/10.1088/1755-1315/1215/1/011008>.
11. Al-Ibrahemi, N., Al-Yassiry, A., Al-Laith, Z. N., & Al-Musawi, B. H. (2023). Phytochemical study of volatile oils for *Ocimum basilicum* L. and *Mentha spicata* by gas chromatography technique. *IOP Conference Series: Earth and Environmental Science*, 1158(5), pp. 1–8.
12. AL-Ibrahemi .N; Hasan.R.M. (2019). Identification of Artemisinin compound in *Artemisia herba alba* belong to the Asteracea by HPLC and GC/MS. *Al-Kufa University Journal for Biology*. 11(2),pp. 8854-2073 .
13. Rohlf, F. J. (2002). NTSYSpc: Numerical taxonomy system (Version 2.1). Exeter Software.
14. Bansal P, Kumar A (2018). Molecular markers in medicinal plant research: Applications and challenges. *J. Genet. Eng. Biotechnol.*, 16(2), pp. 447–455.
15. Befrozfar, M. R., Habibi, D., Asgharzadeh, A., Sadeghi Shoaee, M., & Tookallo, M. R. (2013). Vermicompost, plant growth-promoting bacteria, and humic acid can affect the growth and essence of basil (*Ocimum basilicum* L.). *Annals of Biological Research*, 4(2), pp. 8–12.
16. Banchio, E., Xie, X., Zhang, H., & Paré, P. W. (2009). Soil bacteria elevate essential oil accumulation and emission in sweet basil. *Journal of Agricultural and Food Chemistry*, 57(17), pp. 6531–6536. <https://doi.org/10.1021/jf901151j>
17. Sharma, A. K. (2002). *Biofertilizers for sustainable agriculture: A handbook of organic farming* , pp. 17–18.

18. Darzi, M. T., Mohammadreza, H. A. J., & Seyed, H. M. H. (2012). Effects of organic manure and nitrogen-fixing bacteria on some essential oil components of coriander (*Coriandrum sativum*). *International Journal of Agricultural Crop*, 4(12), pp. 787–792.
19. Bashan, Y., de-Bashan, L. E., Prabhu, S. R., & Hernandez, J. P. (2014). Advances in plant growth-promoting bacterial inoculant technology: Formulations and practical perspectives. *Plant and Soil*, 378(1–2), pp. 1–33. <https://doi.org/10.1007/s11104-013-1956-x>.
20. Bhattacharyya, P. N., & Jha, D. K. (2012). Plant growth-promoting rhizobacteria (PGPR): Emergence in agriculture. *World Journal of Microbiology and Biotechnology*, 28(4), pp. 1327–1350. <https://doi.org/10.1007/s11274-011-0979-9>.
21. Greenacre, M. J. (2016). *Correspondence analysis in practice* (3rd ed.). Chapman & Hall/CRC. ISBN 9781498731775.
22. Husson, F., Lê, S., & Pagès, J. (2011). *Exploratory multivariate analysis by example using R*. Chapman & Hall/CRC. ISBN 9781439835807.
23. Kader, M. A., Mian, M. H., & Hoque, M. S. (2002). Effects of *Azotobacter* inoculants on the yield and nitrogen uptake by wheat. *Journal of Biological Sciences*, 2(4), pp. 259–261.
24. Lebart, L., Morineau, A., & Warwick, M. (1984). *Multivariate descriptive statistical analysis: Correspondence analysis and related techniques for large matrices*. Wiley.
25. Makenova, M., Nauanova, A., Aidarkhanova, G., Ospanova, S., Bostubayeva, M., Sultangazina, G., & Turgut, B. (2023). Organic and biofertilizers effects on the rhizosphere microbiome and spring barley productivity in Northern Kazakhstan. *SABRAO Journal of Breeding and Genetics*, 55(3), pp.972–983. <https://doi.org/10.54910/sabrao2023.55.3.31>