https://doi.org/10.46793/GIRR25.262C

THE IMPACT OF PRODUCTION SYSTEMS ON THE MICRONUTRIENT CONTENT IN TOMATO FRUITS

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ABSTRACT

Tomato (Solanum lycopersicum L.) is one of the most important and widely cultivated vegetable crops worldwide, valued for its nutritional, energetic, and medicinal properties. The growing demand for sustainable agriculture has increased interest in organic and integrated production systems, which limit or eliminate the use of synthetic inputs. This study aimed to examine the content of microelements in tomatoes grown under organic and integrated production systems. Two tomato types (cluster and beef), comprising four different hybrids, were cultivated in a controlled environment using a randomized block design with four replications. The content of chemical elements was determined through multielemental analysis of micronutrients using inductively coupled plasma with quadrupole mass spectrometry (ICP-QMS; iCAP Q, Thermo Scientific X Series 2). The results will contribute to a better understanding of how production systems affect the mineral composition of tomatoes, with implications for food quality and safety in sustainable agriculture.

Keywords: *tomato, microelements, organic, integrated, system production.*

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https://doi.org/10.46793/GIRR25.262C

INTRODUCTION

One of the most intensive branches of plant production, with high accumulation and economic effects, is vegetable production. The profit from vegetable farming is steadily increasing through the cultivation of plants in protected areas. Tomato holds a particularly important place among vegetables as one of the most significant crops. This vegetable is cultivated both for fresh consumption and for processing into finished products, including tomato purée, ketchup, and tomato powder (Fatima et al., 2009). It also contains many nutrients and secondary metabolites important for human health (Cvijanović et al., 2021). Numerous authors have concluded that tomato is rich in vitamins C, E, and B, copper, and iron, as well as minerals such as potassium, sodium, magnesium, and calcium (Setiarti et al., 2022). Solanum lycopersicum L. is cultivated worldwide on over 5,000,000 hectares, with a total production exceeding 190,000,000 tons (FAO, 2023).In the Republic of Serbia, tomatoes are cultivated on 7,782 hectares, with a total production of 113,912 tons and an average yield of 14.64 tons per hectare (FAOSTAT, 2020). Organic vegetable production in Serbia is carried out on 121,559 hectares, of which 4.24% (5,161 hectares) is dedicated to tomatoes. Key challenges in tomato cultivation within integrated and organic systems, particularly for fresh consumption, typically include pest and disease management and weed control (Viler, 2010). The growing consumer demand for high-quality and nutritionally rich products can increase the scope of organic tomato production by using biological products that can contribute to yield enhancement, pathogen control, and higher-quality crops (Cvijanović et al., 2021). Due to the significance of minerals for human metabolism, their analysis is a crucial component of public health studies. The presence of both nutrients and toxic minerals in tomato samples depends on growing conditions and the use of pesticides and fertilizers. Additionally, the accumulation of metals varies greatly among different tomato types and varieties (Bressy et al., 2013). Minerals are micronutrients essential for the growth, maintenance, and proper functioning of the human body (Dramicanin et al., 2021). For normal human function, as many as 22 mineral elements are required, and tomatoes are an excellent source of these minerals (White et al., 2009). Mineral elements are not synthesized within the plant but are absorbed from the soil through the plant's roots. The mineral content in tomato tissues changes during plant growth, with the most significant variations occurring in the days following fruit initiation. Mineral concentrations remain stable during the final stages of crop development (Dramicanin et al., 2021; Duma et al., 2015). The mineral content of tomatoes depends on the availability of minerals in the soil and is significantly influenced by the local geological environment and applied agronomic practices, whether in conventional, integrated, or organic agricultural systems. With growing concerns about human health and the environment due to the intensive use of pesticides in agriculture, identifying sustainable food production systems has become crucial. As a result, organic production is increasingly recommended (Benbrock et al., 2021). Compared to integrated production, organic farming involves the application of natural processes and substances while respecting ecological principles, using renewable energy sources, preserving natural biodiversity, protecting the environment, and limiting or completely eliminating the use of synthetic materials (Ramaraj et al., 2021). Few studies have addressed the connection between metal content in tomatoes and the agricultural systems used in their production (Jorhem et al., 2000; Rossi et al., 2008). Furthermore, it is assumed that the metal content in tomato crops is influenced by various factors, such as soil type, climatic conditions, crop type, and variety selection (Rossi et al., 2008).

The main objective of this study was to identify elements that can serve as specific chemical markers, i.e., indicators of the type of tomato production system. Additionally, the study aimed to establish classification criteria based on elemental content to define the mineral composition of tomatoes, which is important both for assessing their authenticity and for evaluating and determining the type of agricultural system-a relevant issue for both consumers and producers. To identify reliable chemical markers for specific varieties and distinguish between tomato cultivation systems, a set of tomato samples from two-factor randomized trials encompassing eight different varieties and four types, grown under two cultivation systems, integrated (IPM) and organic (O), was analyzed and characterized based on elemental composition. Sixteen microelements and potentially toxic elements (Li, Al, V, Cr, Mn, Co, Ni, Cu, Zn, Mo, Cd, V, Bi, As, Hg, Pb) were quantified using ICP-OES and ICP-MS. The obtained results were processed in MATLAB (Principal Component Analysis). The statistical procedures used confirmed a unique set of parameters that can serve as potential phytochemical biomarkers for differentiating tomato samples belonging to different varieties produced under distinct cultivation systems. This type of research contributes to distinguishing between agricultural systems, integrated and organic, thereby enhancing the capacity to assess and identify key factors for confirming the authenticity of tomato varieties and their production methods. This further raises awareness of the importance of product authenticity, given the significance of food quality data essential for protecting both consumers and producers.

MATERIAL AND METODS

The research was carried out during one growing season in 2020, in controlled microclimate conditions, in order to examine the impact of integrated and organic growing systems on productivity, the number of tomatoes per flower truss and the number of flower trusses in a protected area. The research was conducted on an experimental plot of the company ″Zeleni hit″, in ″13. maj″, in the area in the vicinity of Zemun Polje. The experiment was set up in an indoor facility, of the total area of 320 m^2 (8 m by 40 m), ridge height of 5 m, support height 2.6 m, which enabled continuous support to a larger number of flower trusses and implied descending of the plants.

The experimental parts of the research were designed as two-factorial experiment:

- Factor A: growing system
  - integrated
  - organic;
- Factor B: chosen tomato genotypes, a total of 4 hybrids, two of each of the prevailing types of tomatoes
  - Cluster (hybrids: Dirk and Avalantino)
  - Beef (hybrids: Rally and Velocity)

Prior to seeding, the soil was prepared by using a standard technology: using organic and congenital mineral fertilizers for integrated farming and using only certified and approved organic and mineral fertilizers listed as the approved products for plant nutrition and protection to be used in organic farming.

In both systems, the researchers used bio pesticide agents, useful microorganisms, and predators, as well as pheromone traps and systems of mass trapping to protect crops from pests and diseases. All that was done to harvest the final product without pesticide residues, which was confirmed by certified laboratories.

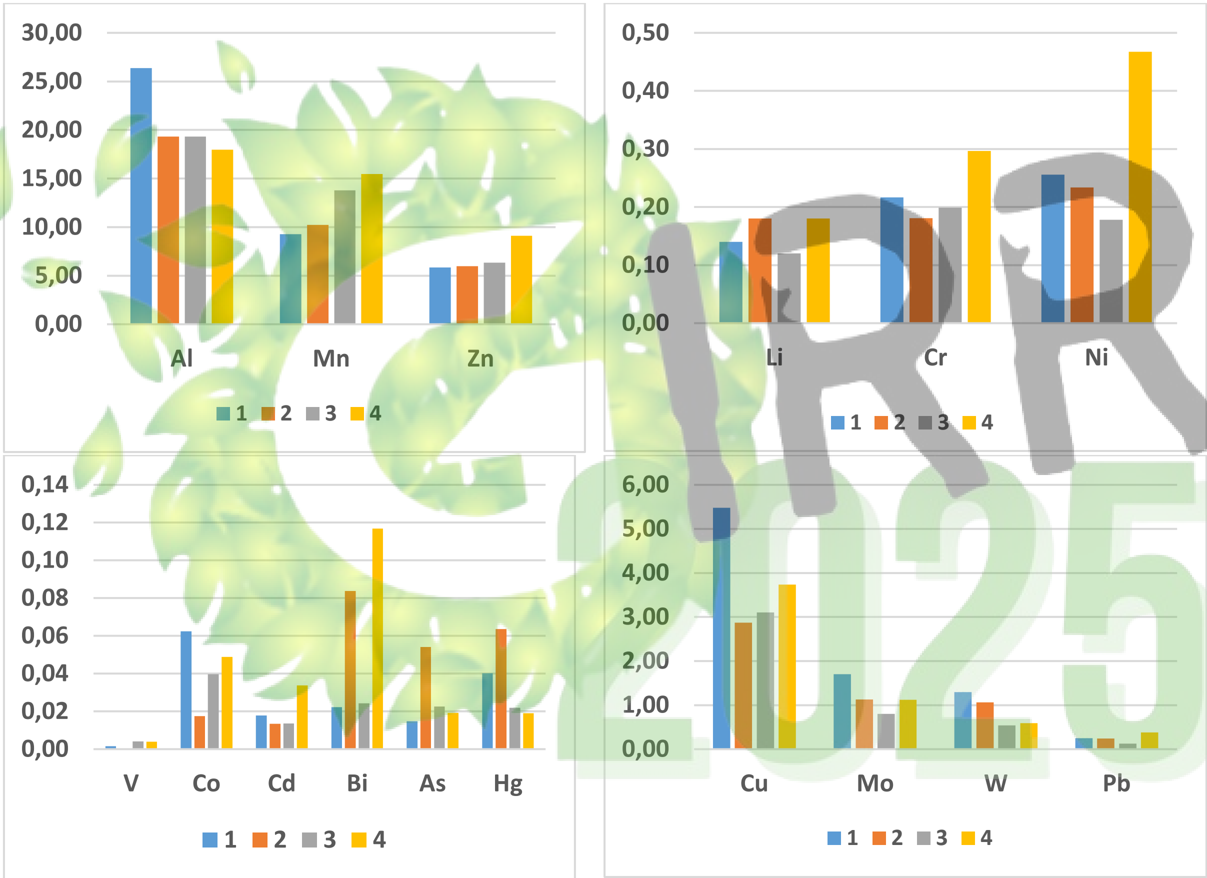
The content of chemical elements was determined through a multielement analysis of micronutrients, using inductively coupled plasma with quadrupole mass spectrometry (ICP-QMS; iCAP Q, Thermo Scientific X Series 2).

https://doi.org/10.46793/GIRR25.262C

RESULTS AND DISCUSSION

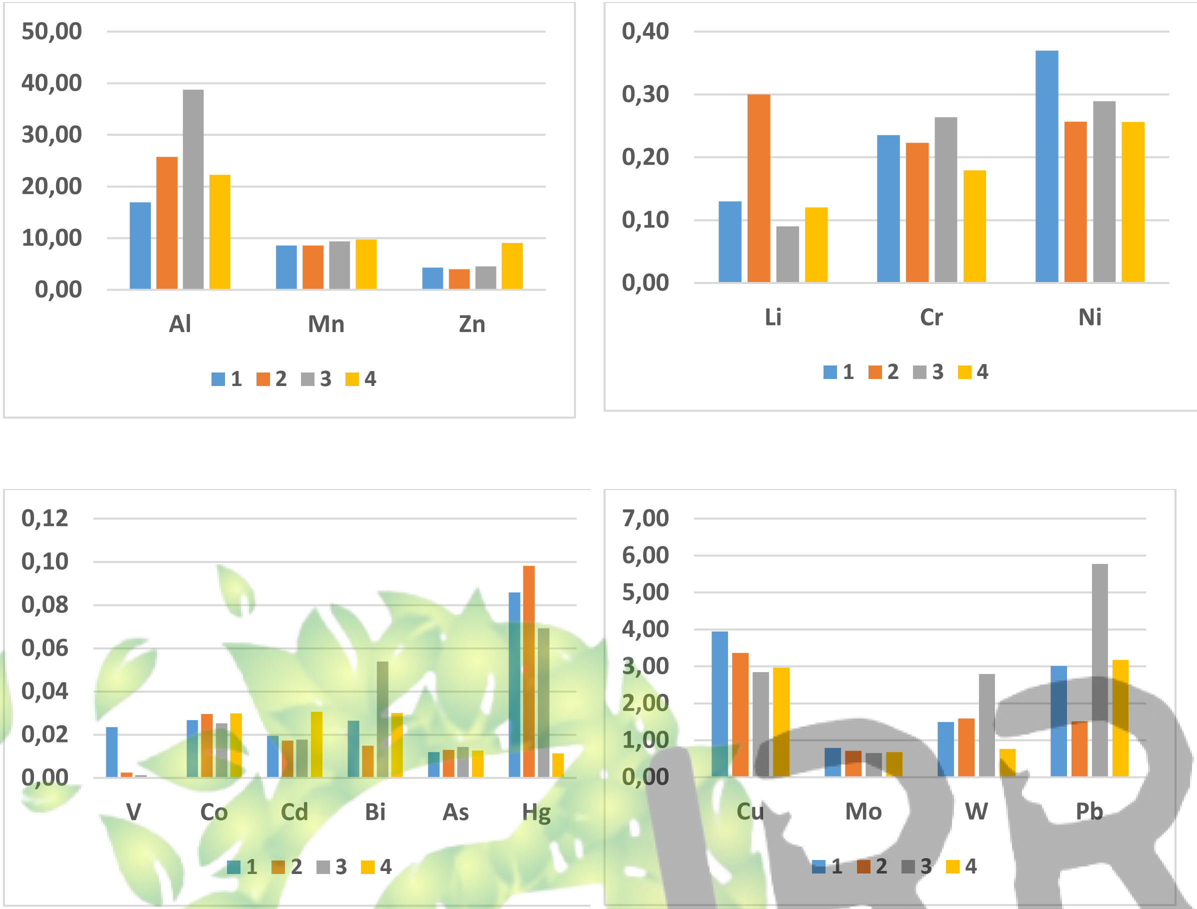
Tomatoes are a rich source of essential elements necessary for maintaining various biological and physiological functions in humans. Minerals, as micronutrients, are crucial for growth, maintenance, and proper functioning of the human body (Dramićanin et al., 2021). The content of mineral elements in tomato fruits depends on the availability of minerals in the soil or substrate, the application of specific technological practices in cultivation (conventional, integrated, or organic farming), climatic conditions, crop type, and the selection of varieties or hybrids. According to numerous studies on the use of biological inputs, particularly those of microbiological origin, it has been proven that the nutritional properties of fruits reach a higher quality (Bressy et al., 2013; Aslam et al., 2018).

Figures 1 and 2 show the determined content of micronutrients in the fruits of tomato hybrids from both cultivation systems.



1. Avalantino, 2. Dirk, 3.Velocity, 4. Rally

Figure 1. Content of micronutrients in the fruits of tomato hybrids from the integrated cultivation system (mg•kg^{-1} dry matter).



1. Avalantino, 2. Dirk, 3.Velocity, 4. Rally

Figure 2. Content of micronutrients in the fruits of tomato hybrids from the organic cultivation system (mg•kg^{-1} dry matter).

Sixteen micronutrients were quantified in the tomato fruits (Table 1). The concentration of micronutrients depends on the pH value of the soil, redox potential, cation exchange capacity, microbial activity, soil structure, organic matter, and water content (White and Broadley, 2009). Concentrations increase as the pH decreases (Mengel et al., 2001). In both cultivation systems, a high variability was found in all types of tomatoes. The content of aluminum and copper was higher in samples from the integrated cultivation system, while the content of manganese and zinc was higher in fruits from the organic cultivation system. The highest aluminum content was found in the Velocity and Dirk hybrids in the integrated system, while in the organic system, the Avalantino hybrid had the highest content. The content of manganese and zinc was higher in samples from the organic system. In both cultivation systems, apple-type hybrids, especially the Rally hybrid, had the highest content of these two micronutrients. Determining the content of these two elements is very important from a human nutrition perspective. Manganese supports several biochemical processes, but due to its immobility, this element moves only to the leaves via the xylem and cannot be transferred to other plant organs. The results obtained are similar to those of Pašković et al. (2021), who found that variations in the nutritional composition of fruits can be the result of arbuscular mycorrhizal fungi activity.

Zinc is a micronutrient involved in the structure and synthesis of proteins, carbohydrate, fat, and nucleic acid metabolism (Palmer and Guerinot, 2009; Hafeez et al., 2013). It increases resistance to diseases and adverse agroclimatic conditions. It also affects the biosynthesis of the plant hormone auxin, which stimulates root system growth and quality rooting.

The increase in zinc content in plants can be achieved through mineral fertilization, applying appropriate agro-techniques that are compatible with the geographic area where production occurs, soil type, and the selection of the appropriate genotype (White, Broadley, 2005).

Among the essential micronutrients, Mo has the lowest concentration in plant tissue, thus it is considered an ultramicroelement. It is a very important element in human nutrition, as its deficiency leads to certain types of anemia that respond exclusively to treatment with iron and molybdenum. In the fruits of tomatoes from the organic cultivation system, a higher concentration of this micronutrient was found compared to fruits from the integrated cultivation system. Molybdenum is part of the enzyme dehydrogenase, which is responsible for redox processes in cells. The effects of molybdenum on plant growth are much greater than the amounts typically found in plants (Kaiser et al., 2005), and its quantity and better availability to plants can be achieved through foliar fertilization.

In fruits from the integrated cultivation system, a higher content of lead was found, while the average content of cadmium was higher in fruits from the organic system. The highest cadmium content in tomato fruits from both integrated and organic cultivation systems was found in the Rally hybrid.

The average copper content was higher in the fruits of hybrids from the integrated cultivation system. The highest copper content in the fruits was found in the Avalantino hybrid from the organic cultivation system, both in the organic and integrated systems. Copper is often associated with the absorption of iron in the human body and the formation of hemoglobin, meaning that without copper, iron would not be utilized in the body. Additionally, copper is closely related to the formation of nerve cells and the process of bone development. The copper content in plants depends on numerous external factors (location, soil type) (Jakšić et al., 2013).

The average cobalt content was higher in the fruits of hybrids from the organic cultivation system and showed greater variations than in fruits from the integrated cultivation system. The highest cobalt content was found in the Avalantino hybrid in both cultivation systems. This element is correlated with the level of organic matter and pH value in the soil. Cobalt has a significant synergistic effect with organic fertilizers on tomato growth, yield, content of biologically active substances, and physical and chemical composition, which can explain its higher concentration in tomato samples from the organic cultivation system (Gad et al., 2013).

The arsenic content was higher in the fruits of hybrids from the organic system, while the mercury content was higher in the fruits of hybrids from the integrated cultivation system. The highest mercury content was found in the Dirk hybrid in both cultivation systems. No mercury was detected in the fruits of hybrids Tomagino, Sakura, Vespolino, and Ardiles from both cultivation systems.

The chromium content was, on average, higher in the organic cultivation system. The highest chromium content was found in the fruits of the Rally hybrid in the integrated cultivation system, while the highest chromium content in the organic system was found in the Velocity hybrid.

CONCLUSION

In addition to macronutrients, 16 micronutrients were quantified. In both cultivation systems, there was significant variability of micronutrients across all types of tomatoes.

The presence of Mn, Zn, Mo, Cd, Co, As, and Cr was detected in the fruits from the organic cultivation system, while the presence of Al, Cu, Pb, and Hg was found in the fruits from the integrated cultivation system. All detected values of the analyzed micronutrients were below the maximum allowable limits. Based on the obtained results, information can be gained for a better understanding of nutrient uptake from the soil. The results can serve as a potential indicator for distinguishing between organic and integrated cultivation systems at a given location. Based on the concentrations of rare earth metals in the fruits, it is possible to assess which elements could serve as potential indicators to confirm product authenticity and provide consumers with sufficient information when choosing food.

REFERENCES

Benbrook, C.; Kegley, S.; Baker, B. Organic Farming Lessens Reliance on Pesticides and Promotes Public Health by Lowering Dietary Risks. *Agronomy* 2021, *11*, 1266.

Bressy, F.C.; Brito, G.B.; Barbosa, I.S.; Teixeira, L.S.; Korn, M.G.A. Determination of trace element concentrations in tomato samples at different stages of maturation by ICP OES and ICP-MS following microwave-assisted digestion. *Microchem. J.* 2013, *109*, 145–149.

Cvijanović V., Sarić B., Dramićanin A., I Kodranov I., Manojlović D., Momirović N., Momirović N., and Milojković-Opsenica D. (2021): Content and Distribution of Macroelements, Microelements, and Rare-Earth Elements in Different Tomato Varieties as a Promising Tool for Monitoring the Distinction between the Integral and Organic Systems of Production in Zeleni hit—Official Enza and Vitalis Trial and Breeding Station Agriculture 2021, 11(10), 1009; doi:10.3390/agriculture11101009

Dramićanin, A.; Andrić, F.; Mutić, J.; Stanković, V.; Momirović, N.; Milojković-Opsenica, D. Content and distribution of major and trace elements as a tool to assess the genotypes, harvesting time, and cultivation systems of potato. *Food Chem.* 2021, *354*, 1–9.

Duma, M.; Alsina, I.; Dubova, L.; Erdberga, I. Chemical composition of tomatoes depending on the stage of ripening. *Chem. Technol.* 2015, *66*, 24–28.

Fatima, T.; Mattoo, A.K.; Rivera-Domínguez, M.; Troncoso-Rojas, R.; Tiznado-Hernández, M.E.; Handa, A.K. Tomato. In *Compendium of Transgenic Crop Plants*, 1st ed.; Kole, C., Hall, T.C., Eds.; Wiley-Blackwell Publishing Ltd.: Hoboken, NJ, USA; John Wiley & Sons Ltd.: Chichester, UK, 2009; Volume 6, pp. 1–45.

Gad N.; Hassan N.M. (2013): Role of cobalt and organic fertilizers amendments on tomato production in the newly reclaimed soil. *World Appl. Sci. J. 22 (10)* 1527-1533 10.5829/idosi.wasj.2013.22.10.27413

Hafeez B., Khanif M. Y., Saleem M. (2013): Role of Zinc in plant nutrition, Journal of experimental agriculture international, 374-391, 10.9734/AJEA/2013/2746

Jakšić S., Vučković M. S., Vasiljević S. Dozet G. Grahovac N., Popović V., Sunjka D. (2013): Accumulation of heavy metals in *Medicago sativa* L. and *Trifolium pratense* L. at the contaminated fluvisol *Hemijska Industrija 67 (1):*95-101. 10.2298/HEMIND1203302045J

Jorhem, L.; Slanina, P. Does organic farming reduce the content of Cd and certain other trace metals in plant foods? A pilot study. *J. Sci. Food Agric.* 2000, *80*, 43–48.

Kaiser B.N.; Gridley K.L.; Ngaire Brady J.; Phillips T.; Tyerman S.D.(2005): The role of molybdenum in agricultural plant production. *Ann. Bot., (96*) 745–754.

Mengel, Konrad, Ernest A. Kirkby, Harald Kosegarten, and Thomas Appel. (2001): Plant Water Relationships. In Principles of Plant Nutrition, *Springer* 181–242.

Miteva, E.; Hristova, D.; Maneva, S. Relationship between viral infection and heavy metals in tomatoes (*Lycopersicon esculentum*). *Bulg. J. Agric. Sci.* 2001, *7*, 435–440.

Palmer C., Guerinot M. (2009): Facing the challenges of Cu, Fe and Zu homeostasis in plants, Nature Chemical Biology 5, 333-340 DOI: 10.1038/nchembio.166

Pasković I., Soldo B., Ban S.G., Radić, T., Lukić, M., Urlić, B., Mimica, M., Brkić Bubola, K., Colla, G., Rouphael, Y. (2021): Fruit quality and volatile compound composition of processing tomato as affected by fertilisation practices and arbuscular mycorrhizal fungi application. *Food Chemistry, 359*, 1–10

Ramaraj, R.; Dussadee, N. Renewable energy application for organic agriculture: A review. *Int. J. Sustain. Energy* 2015, *4*, 33–38.

Rossi, F.; Godani, F.; Bertuzzi, T.; Trevisan, M.; Ferrari, F.; Gatti, S. Health-promoting substances and heavy metal content in tomatoes grown with different farming techniques. *Eur. J. Nutr.* 2008, *47*, 266–272.

White P. J., Broadley M. R. (2005): Trends in plant Science, 10(12) 586-593.

White, P.J.; Broadley, M.R. (2009): Biofortification of crops with seven mineral elements often lacking in human diets–iron, zinc, copper, calcium, magnesium, selenium and iodine. *New Phytol.*, *182*, 49–84.