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**ORIGINAL ARTICLE**

# Mineral Profiling of Various Pine Nut Species Cultivated in Egypt

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Keywords

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A B S T R A C T

Pines are a family of coniferous seed plants with over 100 species, variations, and hybrids. The seeds found in pine cones are known as pine nuts, and a typical cone can carry between 50 and 100 seeds, depending on the year and the species of the pine tree. Each seed has a hard outer shell that encases the kernel. Pine seeds that are large enough to harvest are produced by about 20 species of pine trees. The pine nut is one of the most valuable nuts in the world, and the stone pine is among the oldest fruit trees, as evidenced by archaeological finds dating back to pre-Christian times. Pine nuts, as part of the Mediterranean diet, help lower the risk of several types of cancers, type 2 diabetes, and cardiovascular disease. Pine nuts are in high demand due to their high culinary and nutritional value. In this study, Inductively Coupled Plasma-Optical Emission Spectroscopy (ICP-OES) was used to analyze the minerals of Pinus species growing in various parts of Egypt, including Torrey pine, Italian stone pine, Johann's pine, Coulter pine, Mexican pinyon, Swiss stone pine, and Armand pine. These pines were found to have different minerals, except for Coulter pine, which had no Al or Na. Pine nuts cultivated in Egypt are a rich source of Zn, P, Mn, Mg, and Cu, matching or exceeding the recommended daily intake (RDI) for such minerals while providing between 38% and 84% of the RDI for Fe. In comparison to other types of tree nuts that are usually eaten, pine nuts that are cultivated in Egypt provide a superb supply of nutrients.

## Introduction

Nut crops are among the most important fruit trees because of their high nutritional value (Chatrabnous *et al.*, 2018; Jahanbani *et al.*, 2018; Jahanbani *et al.*, 2021; Pakrah *et al.*, 2021). Pine nuts (*Pinus pinea L.*) have long been popular in European cuisine's sauces, pesto, and dessert garnishes (Bielecka *et al*., 2021; Ríos-Reina *et al*., 2021). Pesto is the most well-known product that contains pine nuts. Olive oil, garlic, pine nuts, and basil are used to make this sauce (Park *et al*., 2016). Pine nuts are in high demand due to the increasing popularity of Mediterranean cuisine throughout Europe (Fig. 1) (Obón-Santacana *et al*., 2020).

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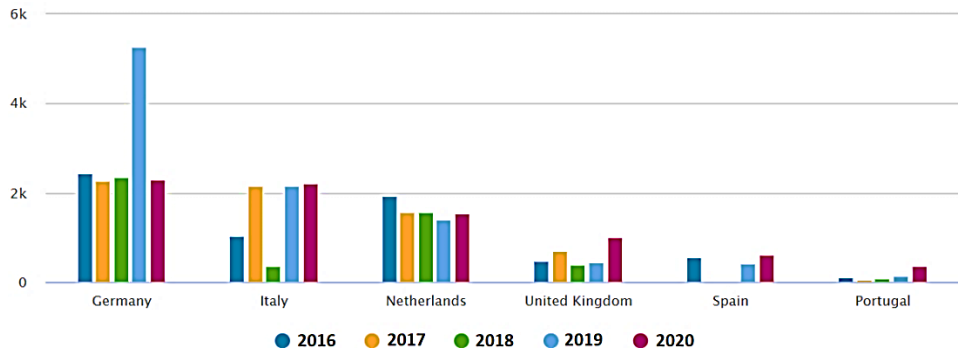


**Fig. 1.** Countries with the highest consumption of pine nuts in Europe (in tonnes).

They are roasted or raw and used in bread, sweets, pastries, vegetable meals, fish, meat, sauces, and cakes (Hoon *et al*., 2015). *Pinus gerardiana*, *Pinus sibirica*, *Pinus koraiensis*, and *Pinus pinea* are the most common species consumed in Europe (Yu *et al*., 2018; Simakhin *et al*., 2021). The future for pine nut consumption in Europe is favorable, with volatility primarily due to predicted changes in foreign supply (Destaillats *et al*., 2010; Mutke *et al*., 2011; Fardin-Kia *et al*., 2012; Awan and Pettenella, 2017). Seeds and nuts are low-water-content dried foods (Hackl *et al*., 2013; Hawthornthwaite *et al*., 2015; Nazoori *et al*., 2022). They are high in numerous nutrients due to their evolutionary adaption to the embryonic feeding of the plants from which they come (Ansari and Gharaghani, 2019; Sharifkhah *et al*., 2020; Grivet and Olsson, 2021; Sarikhani *et al*., 2021). Although all pine trees generate seeds, only a small percentage of them yield huge nuts and edible seeds (Zhang and Zhang, 2019). According to numerous studies, seed and nut lipids have been found to have a good effect on the cardiovascular system, lower blood glucose levels, and reduce insulin need in people with type 2 diabetes (Xie *et al*., 2016; Stróżyk and Pachocka, 2017; Liu *et al*., 2019; Hosseini *et al*., 2020; Ghezel *et al*., 2022). Nuts are prescribed as a replacement for hard cheese, chicken, or a portion of red meat instead of a snack, because of their high energy content (Shirane *et al*., 2021). Because Europe's domestic production is inefficient, expensive, and short of meeting present expectations, most commercial commodities are procured from Russia, China, and Korea, which have climates that are more amenable to efficient production (Fig. 2) (Tanwar *et al*., 2021).

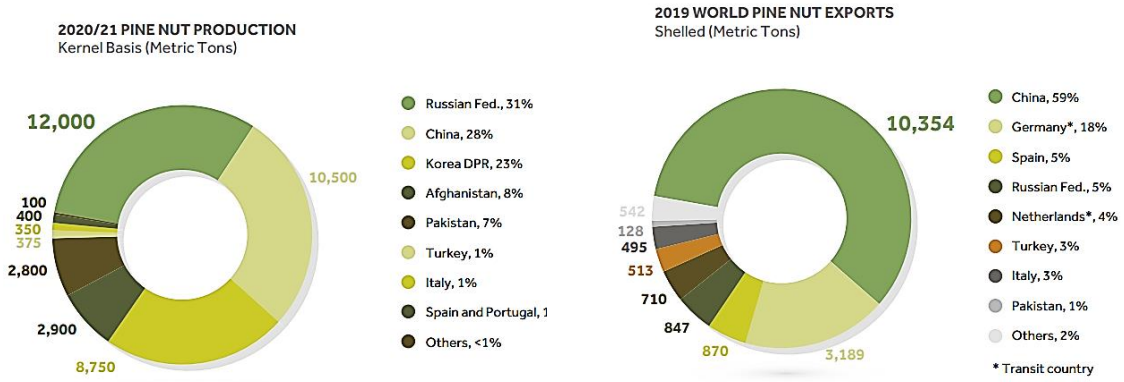


**Fig. 2.** Production of pine nuts worldwide in 2020 and 2021 (left), exports worldwide in 2019 (right).

Only China was responsible for 59% of the world's pine nut exports in 2019, and most of these nuts (50%) end up on shop shelves in the United States, the United Kingdom, and Europe (Khater *et al*., 2020). China's supply is fluctuating. In years when there are limited harvests, increased domestic consumption in Russia and China may reduce the supply of pine nuts for export. Furthermore, China has prohibited imports of North Korea's pine nuts since January 2018, potentially limiting its supply (Flesch *et al*., 2011; Rozhkova *et al*., 2020). The impact of sanctions should never be ignored (Koruzhde and Cox, 2022; Koruzhde, 2022; Koruzhde and Popova, 2022).

Since pine nuts are indeed a forest crop, influencing yields is challenging. As a result, crop yields vary from year to year. Even though the sequence of crop sizes is not regular, various researchers state that there is a sequence in crop production quantity, with crops running in cycles of five: one insignificant crop, one big crop, and three medium-sized crops (Zonneveld, 2011; Protzek *et al*., 2019; Wang *et al*., 2019).

In Egypt, the tree nut industry is growing, especially in places with favorable soil types and macroclimates (Casas-Agustench *et al*., 2011; Salas-Salvadó *et al*., 2011). There has never been a study of *P. pinea* nuts' mineral profile cultivated in Egypt. There have been studies published on the *P. pinea* nuts' mineral profile from around the world that show considerable changes in the pine nuts' chemical constituents and mineral characteristics cultivated in various countries, implying that soil types and the environment play a vital role (Lutz *et al*., 2017; Zuleta *et al*., 2018; Queirós *et al*., 2020; Zulfqar *et al*., 2020; Silva *et al*., 2022). A study analyzed the mineral data for nuts cultivated in Portugal and Turkey. It was discovered that the content of all minerals measured differed significantly (Loewe-Muñoz and Noel, 2021). The researchers also suggested that this variation could be used to distinguish *P. pinea* populations in the Mediterranean. In this research, seven distinct types of pine nuts presently farmed in Egypt were subjected to a comprehensive mineral analysis. The findings were compared to those obtained from a sample of pine nuts that had been imported.

## Material and Methods

Pinus species, including Torrey pine, Italian stone pine, Johann's pine, Coulter pine, Mexican pinyon, Swiss stone pine, and Armand pine were supplied from Egypt's various locations. The Torrey pine was grown in Alexandria, the Coulter and Armand pines were grown in Badr, the Johann and Swiss stone's pines were grown in Cairo, the Mexican pinyon was grown in the Desouk, and the Italian stone pine was grown in the Damietta.

**Table 1.** Varieties of pine nuts which grow in different regions of Egypt.

| **Pinus species** | **Torrey** | **Italian stone** | **Mexican pinyon** | **Johann and Swiss stone** | **Coulter and Armand** |
|---|---|---|---|---|---|
| **Cultivation region** | Alexandria | Damietta | Desouk | Cairo | Badr |

All of the areas utilized for the nuts' cultivation are situated on high-quality agricultural land that was either cultivated previously with oats, lucerne, or mixed pasture grass for animal grazing (Mujani, 2011; El-Zaiat *et al*., 2019). The Italian stone pine can be cultivated in large enough quantities to meet the demand of a commercial market. Damietta has a hot desert climate, but the Mediterranean Sea's blowing winds substantially moderate the temperatures, rendering summers fairly humid and hot and winters mild and moderately rainy with hail and sleet (Table 2). Throughout the year, Damietta receives approximately 3502.83 hours of sunlight (Abou El-Magd and El-Zeiny, 2014).

**Table 2.** Climate data for Damietta, Egypt.

| Site | Average high (°C) | Daily mean (°C) | Average low (°C) | Average precipitation (mm) |
|---|---|---|---|---|
| **Damietta** | 24.5 | 20.2 | 16.0 | 111 |

Cones were dried when they reached maturity, and seeds were then sampled. There had been no cultivar designation or place of origin on one sample of pine nuts acquired online from Abu Auf Company; therefore, it was assumed to be imported. Seeds were ground in a coffee machine, and 0.5g carefully weighed into a Teflon PFA® and Kevlar shielded vessel. This was then mixed with 5mL of nitric and hydrogen peroxide acid (4:1). A microwave digester was used to digest the ground nuts. It was configured to ramp in 15 minutes from ambient to 85$^{o}$C, then in 15 minutes from 85$^{o}$C to 175$^{o}$C, where it was kept for 15 minutes. After the mixture had a chance to cool, deionized (DI), water of 10 mL was supplied to bring the total amount up to 15mL. A VARIAN 720-ES Axial Inductively Coupled Plasma-Optical Emission Spectroscopy (ICP-OES) with SP3 auto-sampler was used to conduct the mineral analysis. Minerals were characterized, and their concentrations were determined by employing either an ICP multi-element standard solution comprised of a single element standard or 23 elements, depending on the requirements. Varian's ICP Expert system software was used to analyze data and standard curves. To calculate the standard error, each batch was performed in triplicate using an ICP multi-element standard solution comprising 0.50 µg g$^{-1}$ of each element and a water test standard. ±0.015 mg kg$^{-1}$ was the total standard error. For each mineral, the limit of quantitation (LOQ), the smallest amount or concentration of a compound that can be determined, was calculated by multiplying the standard deviation of the blank (5% nitric acid) by 10. The LOQ values for each individual mineral spanned anywhere from 0.15 to 13.10 µg L$^{-1}$, with a mean value of 1.97 µg L$^{-1}$.

## Results

In Fig. 3, the mineral profiles of seven types of pine nuts grown in Egypt, as well as the pine nuts purchased from Abu Auf company online, are depicted. Each variety exhibited fourteen distinct minerals in their composition.

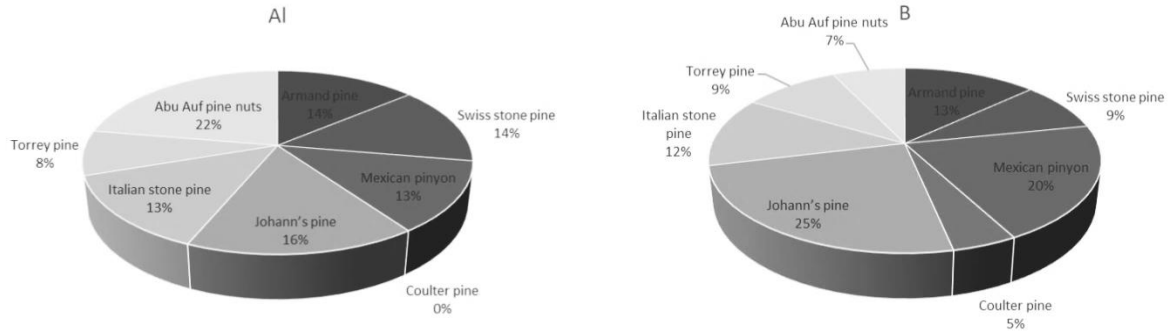


**Fig. 3.** Mineral content (%) of Egyptian pine nuts (n=2).

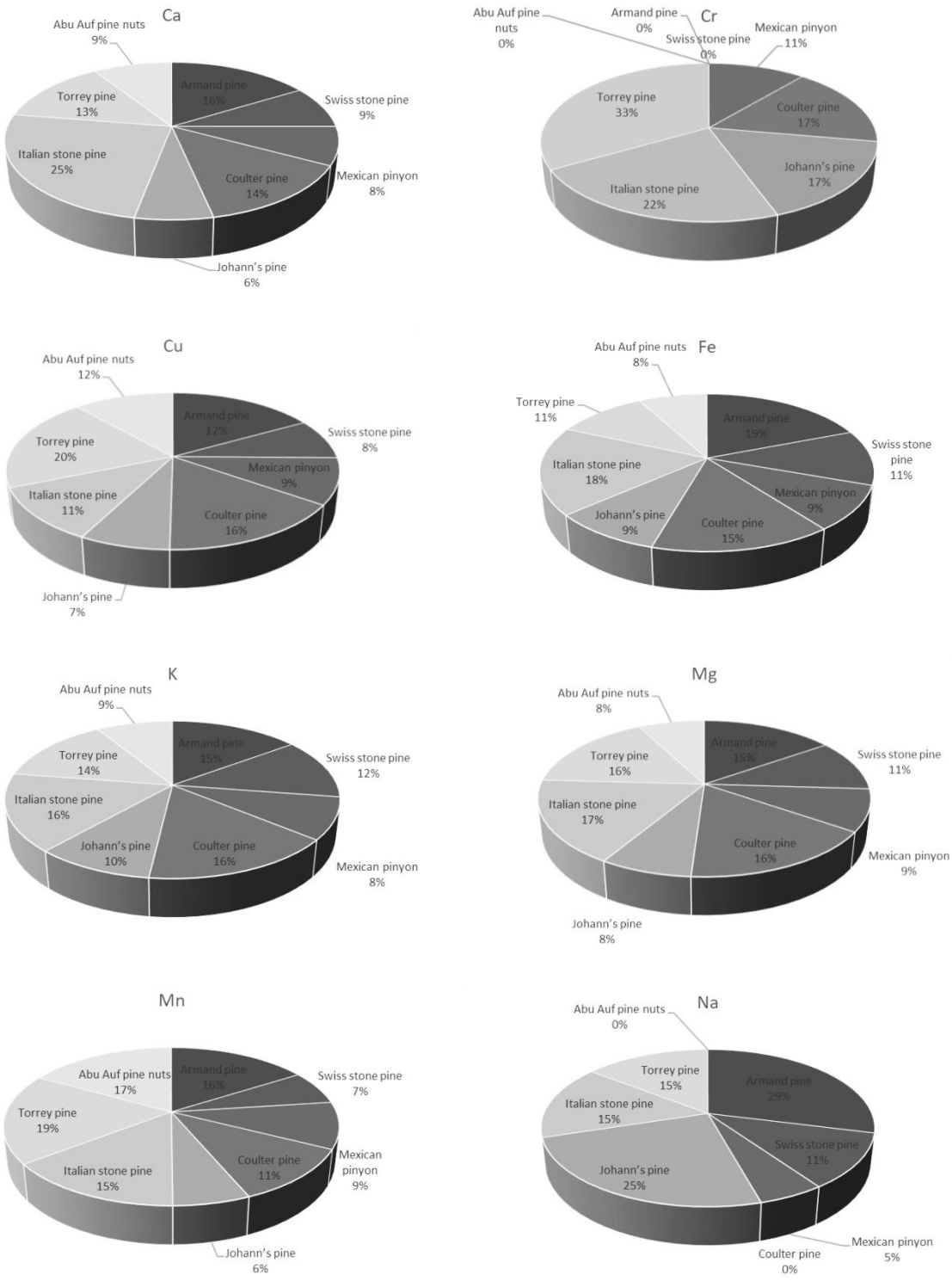


**Fig. 3.** Continued.

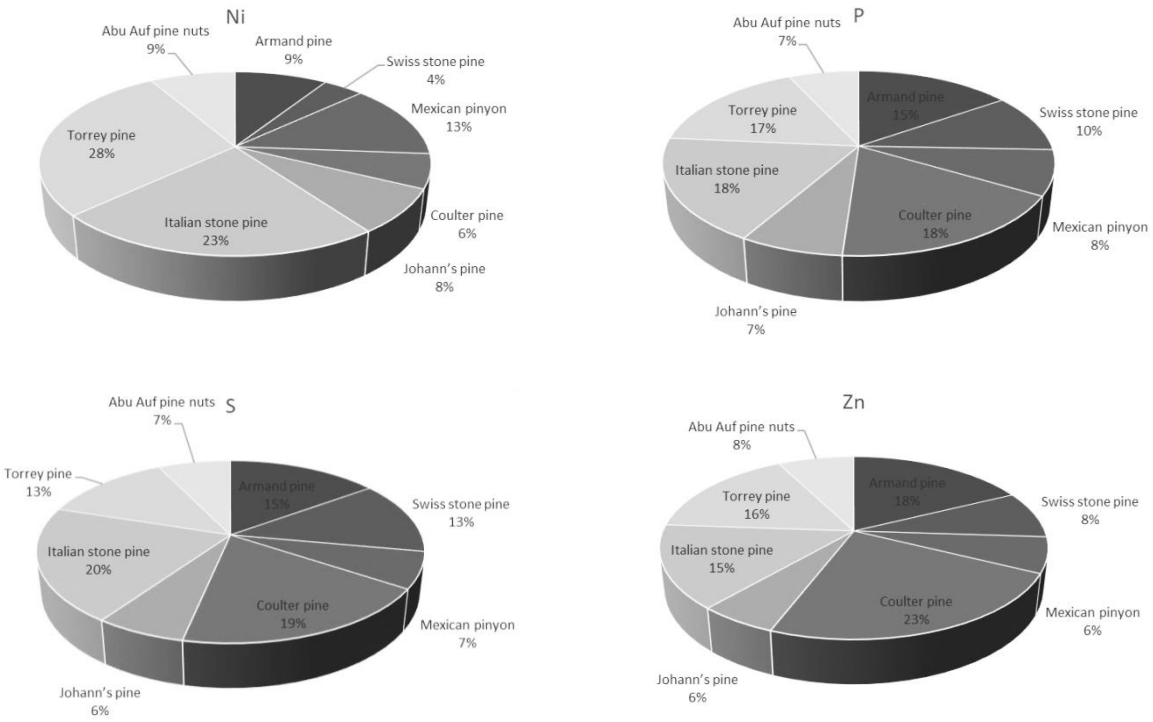


**Fig. 3.** Continued.

In this study, the analysis of Coulter pine samples did not reveal any traceable levels of Al or Na. Similarly, Swiss stone pine and Armand pine samples analyzed in this investigation showed no detectable amounts of Cr. In contrast, Egyptian-grown pine nuts exhibited significantly higher mean values for various minerals such as Zn, S, P, Na, Mg, K, Fe, Cu, and Ca, when compared to the pine nuts imported from Abu Auf company. Interestingly, the average value of Al was lower in the Egyptian pine nuts. However, compared to the Abu Auf pine nuts, the mean values of Ni, Cr, and B were higher, while the mean value of Mn was lower in the Egyptian pine nuts.

The mineral profile analysis conducted using ICP-OES for Egyptian grown stone pine is more extensive compared to other studies that have used older, yet still reliable, methods for mineral analysis (Table 1) (Zuleta *et al*., 2018). The ICP-OES method allows for the simultaneous detection of a wide range of minerals, limited only by the calibration of the equipment, and produces data from a single injection. This makes the process more efficient and enables a more comprehensive view of the mineral profile. By contrast, older methods can be more time-consuming and may not provide as much detail. Therefore, the ICP-OES method is considered more advanced and is preferred for mineral analysis in modern research.

**Table 1.** A comparison between the mineral content (in mg $kg^{-1}$) of stone pine trees grown in Egypt and data previously published from five other countries.

| | Egypt (current study) | Pakistan | Turkey | Canary Island | Aleppo | Austria |
|---|---|---|---|---|---|---|
| **Al** | 31.5 | - | - | - | - | - |
| **B** | 38.4 | - | - | - | - | - |
| **Ca** | 476.5 | 312.6 | 135.2 | 137.2 | 156.8 | 107.8 |
| **Cr** | 0.4 | - | - | - | - | - |
| **Cu** | 19.8 | 33.6 | 14.7 | - | 12.9 | - |
| **Fe** | 139.9 | 109.0 | 100.0 | 43.1 | 54.2 | 40.2 |
| **K** | 14247.9 | 8741.6 | 6987.4 | - | 5850.6 | 5880.0 |
| **Mg** | 7723.1 | 5225.4 | 3185.0 | - | 2459.8 | 2254.0 |
| **Mn** | 114.6 | 157.3 | 67.6 | - | 86.2 | 67.6 |
| **Na** | 3.3 | 9.9 | 114.7 | - | 19.6 | 29.4 |
| **Ni** | 10.2 | - | - | - | - | - |
| **P** | 19421.4 | 11074.0 | 5017.6 | 5047.0 | 5635.0 | 5488.0 |
| **S** | 7734.0 | 4756.9 | - | - | - | 1078.0 |
| **Zn** | 163.1 | 109.0 | 62.7 | - | 63.2 | 51.9 |

As the stone pine boasts the most optimal mineral composition among all the Pinus species cultivated in Egypt, its mineral content was analyzed in comparison to data published from five different countries. In cases where possible, the analysis used the same cultivar (as listed in Table 1), although it should be noted that some of the data sourced from the Aleppo and Austria were not exclusively from the stone pine species. With the exception of copper, manganese, and sodium, the mineral levels were elevated in Damietta, indicating that the region provides an ideal environment for cultivating high-quality goods.

The Damietta region of Egypt boasts the highest annual sunshine hours, with 3610 hours of sunlight being recorded each year. This places it in the same league as other sunny Mediterranean regions. In addition, it has been determined that the soils in Damietta are classified as Entisols, which are considered as recent soils (Alasalvar *et al*., 2020). The soil quality in this area has been classified into five different classes, ranging from excellent to very poor. The Cation exchangeable capacity (CEC) of the soil was found to be in the range of 2.55 to 95 cmol $kg^{-1}$, with an average of 35.08 cmol $kg^{-1}$. These values were observed to be linked with the texture of the soil. These soils are found at an elevation ranging from 80 to 210 m above sea level. The loess-like loam (Loess Orthic Entisols, FAO) possesses several key characteristics that make them ideal for promoting healthy tree growth. One of the most notable features of these soils is their exceptional fertility, which provides a rich source of nutrients for plant growth. In addition, loess soils typically have low levels of organic matter, which can actually be beneficial for trees, as it allows for better drainage and aeration of the soil. Another key characteristic of loess soils is their high cation exchange capacity, which enables them to efficiently absorb and retain essential nutrients that are necessary for tree growth and development.

Also, consuming 62 grams of pine nuts daily can provide a sufficient intake of zinc (Zn), phosphorus (P), manganese (Mn), magnesium (Mg), and copper (Cu), as recommended by the daily intake guidelines. Additionally, this amount of pine nuts can also offer a significant amount of iron (Fe) ranging from 38% to 84%. However, the contribution of aluminum (Al) and boron (B) to the recommended daily intake is negligible, with only 2.3% and 9.8% to 16.4%, respectively. Therefore, including pine nuts in one's diet can provide a good source of essential nutrients, especially for those who may have difficulty meeting

their daily recommended intake levels through other food sources.

**Discussion**

In this study, we investigated the mineral composition of Torrey pine, Egyptian grown Italian stone pine, Johann's pine, Coulter pine, Mexican pinyon, Swiss stone pine, and Armand pine. Our results showed that the mineral profile of Egyptian-grown stone pine nuts was superior to the other pine species studied in terms of its high content of essential minerals such as Zn, S, P, Na, Mg, K, Fe, Cu, and Ca. We also found that the ICP-OES method used for mineral analysis in this study is a more advanced and efficient technique compared to older methods. This conclusion was also arrived at by Queirós *et al*. (2020). Our findings suggest that the Damietta region of Egypt provides an ideal environment for cultivating high-quality stone pine nuts due to its soil quality and high annual sunshine hours. The loess-like loam soils in this area possess several key characteristics that make them ideal for promoting healthy tree growth and providing a rich source of nutrients for plant growth. Therefore, pine nuts grown in this region can offer a significant amount of essential nutrients and be a valuable addition to one's diet, especially for those who may have difficulty meeting their daily recommended intake levels through other food sources. These results are consistent with the study of Zulfqar *et al*. (2020). It is important to note that some of the data sourced from other countries were not exclusively from the stone pine species. Therefore, further studies using the same cultivar from different countries are needed to confirm the superiority of Egyptian-grown stone pine nuts in terms of their mineral composition. In addition, more research is needed to investigate the health benefits of consuming pine nuts and their potential role in improving human health.

Overall, our study provides important insights into the mineral composition of pine nuts from different species and regions, and highlights the importance of using advanced and efficient methods for mineral analysis in modern research. Our findings can also have implications for the food industry and public health, as incorporating pine nuts into the diet can provide a good source of essential nutrients and contribute to a healthy and balanced diet.

**Conclusions**

The nutritional benefits of pine nuts cannot be overstated. Not only are they a great source of essential vitamins and minerals, but they also offer specific advantages in terms of blood lipid levels and heart disease prevention. Egyptian-grown pine nuts, in particular, are an excellent source of essential minerals, exceeding the recommended daily intake for several crucial nutrients like zinc, phosphorus, manganese, magnesium, and copper. Their favorable mineral profile can be attributed to the conducive growing environment in Egypt. Thus, promoting the consumption of Egyptian pine nuts on a larger scale would be a healthy choice for individuals looking to improve their overall nutrition.

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**Conflict of interests**

The authors declare no conflict of interest.

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