Elemental Profile of Some Medicinal Plants from Western Ghats

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Abstract

The present paper deals with the determination of 11 elements in seven medicinally important plants collected from Western Ghats of Maharashtra using ICP-OES technique. The concentration of these elements in these plants showed following order:

Ca > Si > Mg > Na > P > Fe > Al > B > Zn > Mn > Cu

Bioavailability of above elements was also estimated using in-vitro technique. The report also covers statistical analysis of the data obtained.

Key words: Medicinal plants, elemental profile, ICP-OES, bio-availability

1. Introduction

For thousands of years, medicinal plants have been integral to traditional folk medicine. Today, their significance continues to grow across various industries, including pharmaceuticals, essential oil production, food, cosmetics, and even environmental remediation[1–3]. The World Health Organization (WHO) estimates that 80% of people in low and middle-income countries depend on traditional medicine, primarily plant-based remedies, for their healthcare needs[4]. Traditional medicine is often more affordable, widely accepted, and readily available compared to synthetic pharmaceuticals[5].

The medicinal and nutritional properties of plants largely stem from the presence of bioactive chemical compounds, which often include metal ions. Trace elements play a crucial role in the synthesis of these bioactive components[6]. Additionally, they contribute significantly to plant metabolism and biosynthesis by acting as enzyme cofactors, ensuring the plant's overall health. Certain elements, such as zinc (Zn), iron (Fe), copper (Cu), chromium (Cr), and cobalt (Co), are essential nutrients and become harmful only at excessive concentrations. Conversely, elements like lead (Pb) and cadmium (Cd), which lack any known beneficial role, are inherently toxic. The presence of these toxic elements in medicinal plants can result from various environmental factors, including soil contamination, pesticide application, atmospheric deposition, and industrial emissions[7].

Assessing the levels of both essential and toxic elements in medicinal plants is important for understanding their therapeutic efficacy and pharmacological properties. Therefore, analyzing the elemental composition of medicinal plants can provide valuable insights into the appropriate dosage of herbal medicines[6]. The present study focuses on evaluating the elemental content and bioavailability of some medicinal plants from the Western Ghats for which amino acid content were reported in my earlier communication[8].

2. Materials and Methods

2.1 Selection of Plants: The plants were collected from Western Ghats of Maharashtra (Mahabaleswar and Bhimashankar), they were authenticated at Agharkar Research Institute, Pune.

The names of the plants and their medicinal properties are described below:

***Glochidion ellipticum* (Bhoma)**

All parts of Glochidion ellipticum shows medicinal application. Generally, bark, leaves and roots demonstrate analgesic, anti-inflammatory and anti-cancer properties [9]. In the present work, leaves were selected for analysis.

***Aspidium cicutarium* (Kombad nakhi)**

It is used as anti-inflammatory as well as anesthetic. It is used as antidote for snake and scorpion poison. Kombadnakhi guggul (mixture of kombadnakhi and guggul) is used in muscle disorders, skin tumours, lipoma, vericosity, gynaecology disorders[10]. Rhizome is used for the analysis.

***Mimosa pudica* (lazalu bee)**

According to Ayurveda, Root is bitter, acrid, cooling, vulnerary, alexipharmic and used in treatment of biliousness, leprosy, dysentery, vaginal and uterine complaints, inflammations, burning sensation, fatigue, asthma, leucoderma, blood diseases etc. According to the Unani system of medicine, root is resolvent, alternative, useful in diseases arising from blood impurities and bile, bilious fevers, piles, jaundice, leprosy etc.[11]. Seeds of this plant were used for analysis.

Bergenia ligulate (*Pashan Bhed*)

The rhizomes of *Bergenia ligulata* have cooling, laxative, analgesic, abortifacient, aphrodisiac properties. It is used for treating various execratory system disorders like vesicular calculi, urinary discharges, excessive uterine haemorrhage, diseases of the bladder, dysentery, menorrhagia, splenic enlargement and heart diseases [12]. Stem was used for analysis.

***Mesua ferrea Linn* (Nag keshar)**

The plant species is considered as astringent, stomachic, cooling, carminative, expectorant and purgative. Anther of flower was selected for elemental analysis.

***Curculigo orchiodies Gaertn*. (Kali Musli)**

All parts of the plants are useful. According to Ayurveda, roots have heating, aphrodisiac, alternative, appetizer, fattening properties and useful in treatment of piles, biliousness, fatigue, blood related disorders etc. According to Unani system of medicine, root is carminative, tonic, aphrodisiac, antipyretic and useful in bronchitis, ophthalmia, indigestion, vomiting, diarrhea, lumbago, gonorrhea, gleet, hydrophobia, joint pains etc. Roots were selected for analysis.

***Bombax malabaricum D. C.* (shalmali kanta)**

All the parts of the tree have different medical application. The gum, seeds, fruit or its capsule, bark, taproot, cotton and flowers are commonly used. The plant is useful, both, internally as well as externally. The dried flowers or their fresh juice are used to arrest the bleeding in case of piles, raktapitta, dysentery, diarrhoea and colitis. The horns in the form of paste are valuable to treat acne and dispigmentation of the skin. It cleanses the face and imparts fair complexion to the skin[13]. Thorns were selected for analysis.

2.2 Determination of elemental content

The acid mixture was used for digestion parts of the plants, which was prepared by mixing three acids viz. perchloric acid, nitric acid and sulphuric acid in the ratio of 1:3:1 and stored in a glass bottle till further use.

For analysis, 0.1 g of powdered plant sample was mixed with 10 mL of Acid mixture. The mixture was heated for 2 h till a clear solution was obtained. The solution was cooled and transferred to the beaker. The volume of the solution was reduced to 15 -20 mL by heating. The final volume of the solution was made to 50 mL using distilled water. This solution was used for elemental analysis by ICP-OES technique.

2.2 Determination of Bioavailability of different elements

The samples prepared from various plants were subjected to in-vitro digestion, gastric digestion (GD) and gastro-intestinal digestion (GID) for the estimation of bioavailable element from the plants.

2.2.1 Gastric Digestion

1 g of plant sample was transferred into round bottom flask to which 25 mL of gastric juice (6% w/v of pepsin) was added, the pH of the mixture was maintained at 2 using concentrated HCl. The flask was kept in water bath and the temperature was maintained at 37 ^{o}C using a heating coil attached to a controller. The reaction mixture in the flask was stirred continuously for 150 mins. 10 mL of the mixture was transferred, centrifuged for 20 mins with a speed of 2500 rpm. The filtrate obtained was acid digested using acid mixture. This solution was then subjected to ICP-OES analysis for the estimation of elemental contents.

2.2.2 Gastro-intestinal Digestion

Mixture from the gastric digestion was neutralized to pH 7 by drop wise addition of sodium bicarbonate. 20 mL of pancreatic digestion solution (2 % w/v pancreatin and 0.2 % bile salt) was added. The mixture was continuously stirred for another 180 mins at 37 ^{o}C in a water bath. 10 mL of the mixture was centrifuged at 2500 rpm for 20 mins. The filtrate was acid digested and the solution obtained was subjected to ICP-OES for estimation of its elemental contents.

The % bioavailability (% B) of each element in the various plant samples was calculated using the following equation.

$$\%B = \left(\frac{[GD] \text{ or } [GID]}{[T]}\right) * 100 \qquad (1)$$

Where,

GD = concentration of element in Gastric digestion

GID = Concentration of element in Gastro-intestinal digestion

T = Total concentration of element in the plant sample

2.3 Statistical Analysis

The Statistical analysis of the data obtained for the elements was carried out using Pearson's correlation, principal component and cluster analysis.

3.Results and Discussion

The present study provides the elemental profile of seven medicinal plants from Western Ghats of Maharshtra, their bioavailability and statistical analysis.

3.1 Elemental Profile

The group of essential elements include Ca, Cu, Fe, Mg, Mn, P, Na, Zn. Elements such as B and Si may play a biological role but are not classified as essential. Evidences exhibit Al toxicity at high levels. The total elemental concentration of various plants under study is given in Tables 1. The values presented in these table are an average of two with a precision of ± 0.5 to 2 %.

Table 1 ICP-OES Elemental analysis of Glochidion ellipticum, Aspidium cicutarium, Mimosa pudica, Bergenia legulata, Mesua ferrea Linn, Curculigo orchioides and Bombax malabaricum

		Elemental Concentration/ mg g^{-1}						
Elements	Wavelength's nm	*Glochidion ellipticum*	*Aspidium cicutarium*	*Mimosa pudica*	*Bergenia legulata*	*Mesua ferrea*	*Curculigo orchioides*	*Bombax malabaricum*
Al	167	0.4	1.85	1.4	2.05	0.2	0.3	1.1
B	249	0.4	0.1	0.2	0.05	0.05	ND	0.1
Ca	317	9	7.1	3.45	4.35	1.75	27.15	10.75
Cu	324	ND	ND	0.05	ND	0.05	ND	0.05
Fe	238	0.5	2.2	1.45	1.35	0.35	0.5	1.35
Mg	285	2.45	2.3	2.85	1.25	0.8	0.65	0.8

Mn	257	0.1	0.1	0.05	0.05	0.05	ND	0.05
P	213	0.8	0.75	5.45	0.8	1.85	0.25	0.5
Si	251	5.1	4.15	2.6	4.15	0.3	0.85	2
Na	588	1.5	0.65	1	0.75	0.45	0.6	0.7
Zn	213	0.15	0.1	0.05	0.05	0.05	0.05	0.05

*Note- ND: Not Detected

An Examination of Table 1 reveals that calcium is the most abundant element in all the medicinal plants under study ranging from 3.45 to 27.15 mg g^{-1}. *Curculigo orichiodies* showed the maximum concentration of calcium (27.15 mg g^{-1}). The elemental concentration in all the medicinal plants studied showed following order:

Ca > Si > Mg > Na > P > Fe > Al > B > Zn > Mn > Cu

The next most essential abundant element present in all the medicinal plants is Mg ranging from 0.8 to 2.85 mg g^{-1} with highest concentration in *Mimosa pudica*.

All the medicinal plants showed appreciable amounts of iron concentration with maximum concentration found in *Mimosa pudica* to be 1.45 mg g^{-1}. A significant amount of silicon is observed in all the medicinal plants ranging from 0.3 to 5.1 mg g^{-1}, highest being *Glochidion ellipticum*. Silicon plays a key role in enhancing resistance towards physiological base stresses, thereby improving the growth[14].

High levels of aluminium exhibits toxicity in living organisms. In humans, excess Al acts a neurotoxin whose effects are known particularly in patients with chronic renal failure[15, 16]. The concentration of aluminum ranges from 0.2 to 2.05 mg g^{-1}, highest in *Bergenia legulata*.

The concentration of elements varies from plant to plant and is attributed to factors such as absorption capacity of a particular plant for corresponding elements, age of the plant and mineral constituents of soil and climatic conditions in which the plant grows.

3.2 Statistical Analysis

The Statistical analysis of above data was carried out using Pearson's correlation, principal component and cluster analysis.

3.2.1 Pearson's Correlation

To understand the interaction of elements it is necessary to study the correlation between the elements. Pearson's correlation test helps to understand the one-to-one correlation between the parameters having coefficient numbers varying from -1 to +1. The closer this coefficient to -1 or +1, stronger the relationship between the two variables and if coefficients are close to '0' then there is a very weak or no correlation between the two variables [17]. The Pearson's correlation test was performed using the IBM SPSS software (version 17) and the correlation coefficient matrices are given in the Table 2

Table 2 Pearson's correlation values for various elements studied in different plants

Elements	**Al**	**B**	**Ca**	**Cu**	**Fe**	**Mg**	**Mn**	**P**	**Si**	**Na**	**Zn**
Al	1										
B	-0.190	1									
Ca	-0.395	-0.186	1								
Cu	-0.176	-0.116	-0.410	1							
Fe	**0.889****	-0.147	-0.294	-0.069	1						
Mg	0.345	0.704	-0.411	-0.104	0.424	1					
Mn	0.134	0.634	-0.215	-0.469	0.298	0.624	1				
P	0.136	0.206	-0.473	0.573	0.141	0.575	-0.210	1			
Si	0.534	0.620	-0.283	-0.570	0.439	0.667	0.747	-0.101	1		
Na	-0.071	**0.962****	-0.104	-0.243	-0.120	0.681	0.539	0.178	0.701	1	
Zn	-0.133	**0.813***	-0.053	-0.510	-0.031	0.562	**0.921****	-0.246	0.719	0.748	1

[**. Correlation is significant at the 0.01 level (2-tailed)]. [*. Correlation is significant at the 0.05 level (2-tailed)].

An examination of Table 2 illustrates that pairs of Na-B (0.962), Fe-Al (0.889), Zn-B (0.813), Zn-Mn (0.921) showed the most relevant and significant correlations. Mg showed maximum moderate positive correlation amongst other 8 elements Zn (0.562), Na (0.681), Si (0.667), P (0.575), Mn (0.624), Fe (0.424) and B (0.704). Ca and Cu is negatively correlated with all the other elements. The positive correlation can be due to similar source for elements, geographical origin or soil[18]. The same assumptions are stated by Tokalıoğlu[19].

3.2.2 Principal Component Analysis

PCA is a power variable reduction tool that helps in overcoming redundancy in the data. This results in a small number of artificial variables in the form of principal components. These components can be used as predicator variables in subsequent analysis. Figure 1 represents the eigen values plotted against the component numbers.

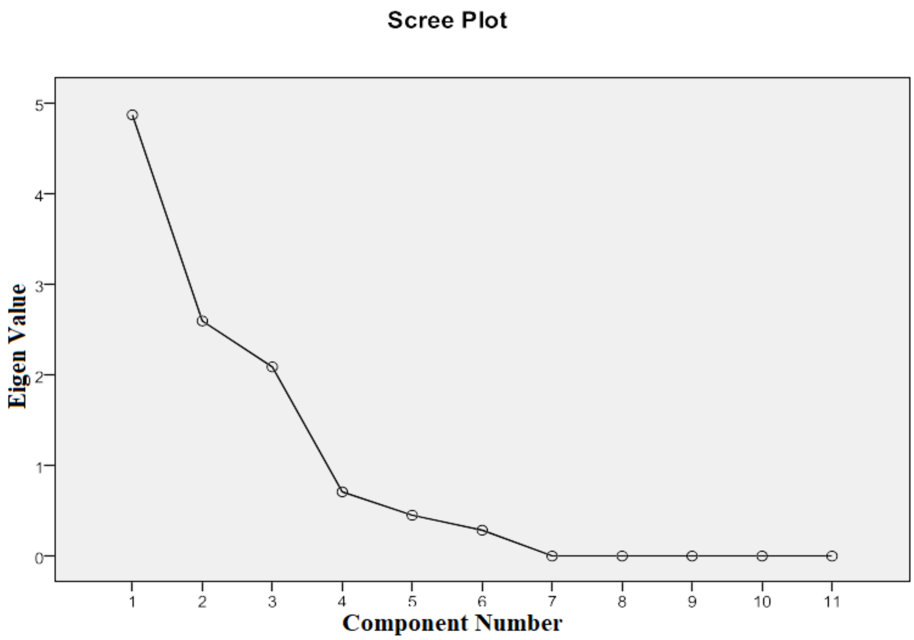

Fig.1 Scree plot showing the Eigen values for each component

Eigen value > 1 are considered for principal components. (In Principal Component Analysis, eigen values represent the amount of variance explained by each principal component) In this plot, 3 components have eigen values > 1. Hence, 3 principal components have been selected. The first component explains about 42 % of the total variance observed in the data. The second component comprises of about 23.5 % of the total variance and third component constitutes about 19 % total variance. Cumulative variance explained by the three components is about 87 % of the total variance.

Principal components and loadings against each element are shown in the Table 3

Table 3 Principal components and variable loadings

Elements	**Component**		
	1	**2**	**3**
Al	-0.025	**0.971**	0.066
B	**0.942**	-0.209	**0.203**
Ca	-0.185	**-0.395**	**-0.645**
Cu	-0.380	-0.215	**0.796**
Fe	0.013	**0.941**	0.075
Mg	**0.760**	**0.366**	0.**426**
Mn	**0.823**	0.273	-0.236
P	0.058	0.071	**0.924**
Si	**0.790**	**0.527**	-0.173
Na	**0.916**	-0.137	0.127
Zn	**0.931**	-0.045	**-0.275**

An examination of Table 3 illustrates that in the first component, B, Na and Zn have the largest loadings of 0.942, 0.916 and 0.931, respectively. These elements are followed by Mn, Si and Mg with loadings of 0.823, 0.790 and 0.760, respectively which can also be seen by Pearson correlations. The second component comprises of Al (0.971), Fe (0.941) and Si (0.527). Al and Fe having similar loading suggesting a positive correlation. Ca and Mg might be antagonistic to each other as the similar magnitudes of loading are similar but in opposite directions. Third component comprises primarily of Si followed by Cu and Ca. Cu and Ca might be antagonistic to each other. Similarly, Zn and B. As can see from the table similar loadings are observed for B, Na and Zn. These correlations are in good agreement with Pearson correlation.

3.2.3 Cluster analysis

It is an indirect method of multivariate statistical analysis. Dendrogram is a plot showing the clusters of variable at different horizontal distances. It is useful in recognizing groups of variables based on their similarity. The lesser the horizontal distance at which the clusters are formed, greater is the similarity between the variables. In this study cluster analysis is done using Ward's method and squared Euclidean distance. Fig 2 Shows the cluster analysis of the elements of various plants under study.

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Dendrogram using Average Linkage (Between Groups)

                        Rescaled Distance Cluster Combine

   C A S E      0         5        10        15        20        25
  Label         +---------+---------+---------+---------+---------+

  Mn            -+
  Zn            -+
  Cu            -+
  B             -+
  Na            -+
  Al            -+
  Fe            -+-+
  Mg            -+ +---------------------------------------------+
  P             -+ |                                             |
  Si            ---+                                             |
  Ca            -------------------------------------------------+
```

Fig. 2 Cluster Analysis

As can be seen from Fig 2 three main clusters are formed. Cluster 1 comprises of Mn, Zn, Cu, B, Na, Al, Mg and P. Cluster 2 combination of Fe and Si. Cluster 3 is a secondary cluster between Ca and cluster 2 forming at horizontal distance of about 25 units indicating large dissimilarity between Ca and cluster 2.

3.3 Bio-availability of elements

Bio-availability of different elements in the medicinal plants under study were carried out by in-vitro method. In in-vitro method the plant material is subjected to simulated gastric and gastro-intestinal digestion and the amount of soluble and ionizable elements present in plants have been measured as an index of its bio-availability[20-22].

The results obtained for the percentage bioavailability of elements in the investigated plants are summarized in Table 4. The values presented in these table are an average of two with a precision of ± 0.5 to 2 %.

The % Bio-availability of sodium was found to higher than 100 % as sodium was used for pH control.

Table 4 The percentage Bio-availability of different elements in medical plants

Element	*Glochidion ellipticum*		*Aspidium cicutarium*		*Mimosa pudica*		*Bergenia legulata*		*Mesua ferrea*		*Curcuilgo orchioides*		*Bombax malabaricum*	
	% Bio-availability of element													
	GD	**GID**	**GD**	**GID**	**GD**	**GID**	**GD**	**GID**	**GD**	**GID**	**GD**	**GID**	**GD**	**GID**
Al	3.1	22.5	6.7	0.9	5.3	1.2	1.2	0.8	12.5	9	20.8	24	2.2	4.9
B	3.1	4.5	12.5	40	18.7	45	12.5	39	10	80	BD	BD	37.5	90
Ca	25.6	25	30.6	1.2	39.1	2.6	85.9	2	54.2	5.1	4.9	0.3	16	0.8
Cu	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD
Fe	5	14.4	5.1	2.4	6	3.7	1.8	2.6	10.7	15.4	10	10.8	1.8	5.3
Mg	68.7	50	70.7	78.2	75.4	63.1	68	63.3	95.1	96.7	82.1	85.3	42	60.4
Mn	50	36	25	36	50	72	25	36	50	36	BD	BD	25	36
Si	2.9	2.1	3	2.1	6.2	3.5	1.8	2.1	20.8	42	13.2	25.4	3.1	10.8
Zn	43.8	35.7	22	35.2	39.5	72.3	21.8	35.9	38.7	34.8	BD	BD	23.8	36.8

*Note: BD:- Below detection Limit

An examination of Table 4 reveals that in all plant samples the bioavailability of elements is maximum in GID than GD, as expected. The bioavailability of elements followed the following trend in GD and GID respectively

Mg > Ca > Zn > Mn > B > Si > Al > Fe and **Mg > B > Mn** ≈ **Zn > Si > Ca > Al > Fe.**

Bio-availability of Mg is found significantly high in all the plant samples ranging from 42 – 95.1% in GD and 50 – 96.7% in GID. Calcium is one of the most essential element required by the body. The bioavailability of calcium ranges from 4.9 – 85.9% in GD and 0.3 – 85.9 in GID. The bioavailability of Al, Fe and Si were found to be low as compared to Mn and Zn in all the medicinal plants studied. Cu was below detection level in all the plants while Mn and B were below detection limit in *Curculigo Orchioides*. Thus, these plants can also act as good source of nutrients.

Conclusions

The elemental profile of different medicinal plants was determined using ICP-OES technique and in-vitro assay was used to study the bioavailabilty of estimated elements. It was observed that the elemental content in all the plant samples varied considerably. The concentration of the elements in the medicinal plants showed following order:

$$Ca > Si > Mg > Na > P > Fe > Al > B > Zn > Mn > Cu$$

From the in-vitro studies it was observed that the bio-availability of the elements in GID is higher than that of GD as excepted. The data of elemental composition for the medicinal plants can be a useful tool for deciding the dosage of herbal drugs.

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Author's contribution

Author has planned the experiments, carried out the work and written the manuscript

Conflict of interest

There is no any conflict of interest

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