

Mineral Composition of *Xanthium strumarium* L. Across Contrasting Habitats

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ABSTRACT

Environmental conditions play an important role in determining the mineral composition of medicinal plants, which can ultimately influence their therapeutic value. *Xanthium strumarium* L. is a well-known medicinal plant used in traditional healthcare systems, yet limited information is available regarding how different habitat conditions affect its elemental composition. The present study was conducted to investigate the macro- and micro-elemental composition of roots, stems, and leaves of *Xanthium strumarium* collected from two contrasting habitats of Baramati tehsil, Maharashtra, India—one saline site (Mekhali) and one non-saline site (Pimpali). Plant samples were shade-dried, oven-dried, and powdered before being subjected to di-acid digestion using HNO₃ and HClO₄. Macro-elements were estimated using a flame photometer, while micro-elements were determined using Atomic Absorption Spectrophotometry (AAS). Statistical analysis was performed using one-way ANOVA followed by Tukey's test ($p < 0.05$). The results showed that plants growing in the non-saline habitat contained higher levels of nitrogen, phosphorus, and potassium in their aerial parts, suggesting better nutrient availability and uptake. In contrast, plants from the saline habitat showed greater accumulation of micronutrients such as iron, zinc, manganese, and copper, particularly in the roots, along with increased sodium content. These findings indicate that habitat conditions significantly influence elemental distribution in *X. strumarium* and reflect the plant's adaptive response to salinity stress.

1. Introduction

Medicinal plants have been used in traditional healthcare systems for centuries and continue to serve as important sources of therapeutic compounds. Their medicinal value is largely attributed to the presence of bioactive phytochemicals and essential mineral elements that contribute to various pharmacological activities (Hussein & El-Anssary, 2019; Chen *et al.*, 2022). Environmental factors such as soil

composition, temperature, salinity, altitude, and nutrient availability strongly influence plant metabolism and the accumulation of these bioactive compounds (Shaista & Zahoor, 2022). Mineral nutrients play a crucial role in plant growth and development and participate in numerous physiological and biochemical processes. These elements are absorbed from the soil, and their concentrations vary depending on

soil characteristics and environmental conditions (White & Brown, 2010). In medicinal plants, both macro- and micro-elements contribute to therapeutic effectiveness and influence the quality and safety of herbal medicines (Narendhirakannan *et al.*, 2005).

Environmental stresses such as drought, salinity, and heavy metal exposure can significantly alter the uptake and distribution of mineral elements in plants, thereby affecting metabolic processes and medicinal properties (Jan *et al.*, 2015). Among these factors, soil salinity plays an important role in regulating ionic balance and nutrient assimilation, which may lead to variations in elemental composition among different plant tissues. The use of medicinal plants remains widespread worldwide, particularly in developing countries where traditional herbal remedies are commonly used for primary healthcare. It is estimated that nearly 80% of the global population relies on medicinal plants for the treatment of various diseases (Miranda, 2021). These plants are utilized in various forms such as herbal preparations, essential oils, dietary supplements, and spices (Balaji & Mahalingam, 2025). *Xanthium strumarium* L., a member of the family Asteraceae, is widely distributed in tropical and subtropical regions and has long been used in traditional medicinal systems across Asia. The plant is known to possess several pharmacological properties, including antimicrobial, anti-inflammatory, and

antioxidant activities, which are associated with its phytochemical and elemental composition.

Although several studies have investigated the phytochemical constituents of *Xanthium strumarium*, limited information is available regarding the influence of environmental conditions on its elemental composition. Therefore, the present study aims to evaluate the elemental profile of roots, stems, and leaves of this species collected from saline and non-saline habitats of Baramati tehsil, Maharashtra, India. Understanding habitat-based variations in elemental composition will help assess the nutritional significance and medicinal potential of this species. Elements are essential for the synthesis of several bioactive components in medicinal plants. They are believed to be in charge of plants' poisonous and therapeutic qualities. Certain components are necessary for the human (Niamat, R. *et al.*, 2012). Plants contain a wide variety of mineral elements, including trace, macro, and micro elements. Because of the properties of the soil and the growing environment, each plant has a different amount of each element (White, P.J and Brown, P.H., 2010).

2. Materials and Methods

2.1 Collection and identification of Plant material

Field exploration was carried out in Baramati with two different contrasting localities (i.e saline and non-saline habitats) were collected. Plant Herbarium were prepared using standard

protocol and identified at Department of Botany, Savitribai Phule Pune University, Pune.

2.2 Preparation of the Samples.

Collected *X. strumarium* L. Roots, stem and leaves samples from contrasting habitat were washed using running tap water followed by distilled water to remove dust. cleaned plant material cut into small pieces and subjected to dry under shade condition, upto 2 weeks and then dried in electrical-oven at 55⁰C for 24 hours.

2.3 Sample preparation and Di-acid digestion.

One gram of powdered root stem and Leaves of *X. strumrium* was placed in a 100 mL conical flask. To the flasks, add 10 mL of a 9:4 acid mixture (HNO and HClO) and swirl to mix. Flasks were placed on a heated plate at low heat in a digestion chamber. The flasks were gradually heated from 100 °C to 280 °C in three steps until no red vapours were produced. The first step involved maintaining a temperature of 100 °C for 30 minutes. In the second stage, the temperature was increased to 150 °C and held for 30 minutes. The third step involved maintaining a temperature of 280 °C for 120 hours. The ingredients are evaporated to 3-5 mL. When the liquid turned colorless, it meant digestion was complete. After cooling the flasks, 20 mL distilled water was added. The solutions were transferred to a 100 mL volumetric flask and diluted to volume. The solution's pH remained below 2.0. The solution was filtered with 0.45micron filter paper. Calibration curves were created using standard working solutions to calculate the concentration of the target element

in the sample by absorption measurements. The solution was filtered with 0.45-micron filter paper. Calibration curves were created using standard working solutions to calculate the concentration of the target element in the sample by absorption measurements (Senila, M.,(2014), Ozhukayil, J. J. (2015)).

2.3.1 Determiration of N, P and K

Diluted a 10 mL digested sample with 100 mL of distilled water. Standard curves for K and Na were created by graphing measurements against various concentrations (5, 10, 15, and 20 µg/mL). The samples were evaluated using a Flame Photometer (CL 378, Elico India, Private Limited) at 589.0 nm, 526 nm and 766.5 nm for N, P and K, respectively.

2.3.2 Determiration of Ca, Mg, S, Fe, Mn, Cu, Zn, Na, Cl

Determiration of Ca, Mg, Fe, Mn, Zn, Cu, Na, and Cl Aliquots of digested samples were analyzed for Fe, Mn, Zn, Cu, Na and Cl. To measure Ca and Mg concentrations, an aliquot of the material was diluted. The concentration of each element was determined with an Atomic Absorption Spectrophotometer (Analytik Jena GmbH-novAA 300) (Senila, M.,2014). Table-1 shows the operational parameters for AAS.

2.3.3 Validation of AAS method AAS

AAS was validated by estimating accuracy, LOD, and LOQ. The method's accuracy was evaluated against certified reference material SQC014 [Sigma-Aldrich (Merck) Spectroquant®] and reported as a percentage recovery shown in Table-2.

2.3.4 Statistical analysis

Statistical analysis was performed using SPSS software. Triplicate values are taken from each experiment and Findings are represented as Mean \pm Standard deviation. The statistical analysis was performed by using one way-ANOVA followed by Tukey's multiple comparison test.

3. Result and Discussion-

Earlier work by Azimbaeva et al. (2020) showed that *Xanthium strumarium* L. mainly accumulates manganese in its leaves and stems, followed by iron, copper, and zinc. Building on this, the present study examined how elemental composition varies in leaves, stems, and roots of *X. strumarium* L. growing in two contrasting habitats, Mekhali and Pimpali. Clear differences in nutrient distribution were observed between the two sites. Plants collected from the Pimpali site showed higher accumulation of macronutrients, particularly in their above-ground parts. Nitrogen content was noticeably higher in the leaves and stems from Pimpali, while roots from the Mekhali site stored more nitrogen. Phosphorus levels were similar in leaves from both locations, but stems and roots from Pimpali contained comparatively higher phosphorus. Potassium showed the most striking variation, with stems from Pimpali accumulating nearly three times more potassium than those from Mekhali, although leaf potassium levels remained almost the same at both sites. In contrast, plants from the Mekhali site were richer in micronutrients. Iron, copper, zinc, and

manganese were present in significantly higher amounts, especially in the roots, suggesting that below-ground parts play a key role in micronutrient storage under these conditions. Iron content was consistently high in all plant parts from both habitats, while copper, zinc, and manganese were particularly elevated in Mekhali samples.

Overall, *X. strumarium* L. growing in Mekhali shows a strong ability to retain micronutrients in its roots, whereas plants from Pimpali tend to allocate more macronutrients to leaves and stems. The high iron content observed across all samples supports the potential use of this plant as a natural source of iron and its traditional application in the treatment of anemia. Ionic elements exhibited distinct site-specific variation. Leaves of *Xanthium strumarium* L. from the Mekhali site showed higher sodium accumulation than those from Pimpali, while root sodium levels were comparable between sites. Chloride distribution varied significantly among plant parts, with higher concentrations in leaves and roots from Mekhali, whereas stems from the Pimpali site exhibited markedly elevated chloride levels.

Overall, *X. strumarium* L. from Mekhali demonstrated preferential accumulation of micronutrients (Fe, Zn, Cu, and Mn), particularly in roots, indicating adaptation to nutrient-limited or saline soil conditions. In contrast, plants from Pimpali showed enhanced accumulation of macronutrients (N, K, Ca, and S) and chloride in

aerial tissues, supporting improved growth under more favourable environmental conditions.

Table-1. Operating Parameters of elemental analysis using Atomic Absorption Spectrophotometer.

Elements	WL (mm)	Slit width	Flame type	Lamp intensity (mA)	Calibration R ² ACC	Burner Height
N	-	-	-	-	-	-
P	-	-	-	-	-	-
K	7.66	0.2	Air- C2H2	10	0.9979	10
Ca	422.7	0.5	Air- C2H2	10	0.9991	6
Mg	285.2	0.5	Air- C2H2	04	0.9999	4
S	182.0	0.2	Air- C2H2	10	0.9981	4
Fe	248.3	0.5	Air- C2H2	07	0.9983	6
Mn	279.5	0.2	Air- C2H2	07	0.9985	6
Zn	213.9	0.2	Air- C2H2	05	0.9999	6
Cu	324.8	0.5	Air- C2H2	07	0.9976	6
Na	589.0	0.2	Air- C2H2	12	0.9988	10
Cl	-	-	-	-	-	-

Note- Nitrogen, Phosphorous and Chloride analysed by Flame Photometer.

Table -2 LOD, LOQ and % recovery of the Elements under the study

Sr. No	Elements	LOD (mg/kg)	LOQ (mg/kg)	% Recovery
1	N	-	-	-
2	P	-	-	-
3	K	0.023±0.023	0.059±0.004	94±1
4	Ca	0.011±0.056	0.027±0.02	95.33±3.05
5	Mg	0.0047±0.07	0.016±0.015	96±2.64

6	S	0.0035±0.005	0.010±0.008	96.8±2.5
7	Fe	0.005±0.007	0.015±0.006	94.66±3.21
8	Mn	0.0013±0.001	0.0033±0.003	93±3.60
9	Zn	0.0012±0.005	0.0029±0.002	93.66±1.15
10	Cu	0.0015±0.07	0.0028±0.015	96±2.64
11	Na	0.009 ±0.001	0.031±0.002	94.33±3.05
12	Cl	-	-	-

Medicinal plants play a vital role in traditional healthcare systems and remain important sources for modern drug discovery due to their diverse phytochemical and elemental composition. In the present study, *Xanthium strumarium* L. collected from two contrasting habitats contained measurable levels of essential macro- and micro-elements, including Na, K, P, Ca, Mg, Fe, Zn, Mn, Cu, and Cl. Among macronutrients, potassium showed pronounced habitat-dependent variation, with the highest concentration recorded in stems from the non-saline site and significantly lower levels under saline conditions. Iron was the most abundant micronutrient and showed markedly higher accumulation in plants from the saline habitat,

particularly in leaves and roots, compared to those from the non-saline site. These differences likely reflect variations in soil chemistry, ion availability, and stress-induced nutrient uptake mechanisms associated with salinity.

Since mineral nutrients are essential for plant metabolic and physiological processes, and their availability is strongly influenced by soil and environmental factors, the observed elemental variation highlights the role of habitat conditions in regulating nutrient assimilation in *X. strumarium* L. Such habitat-driven differences in elemental profiles are critical for assessing the medicinal quality of the species and may have direct implications for its pharmacological efficacy.

Table -3 Composition of elements in leaves, stem and root of *X. strumarium* L. from Mekhali, Baramati, Maharashtra.

Parameter	Leaf (%/ppm)	Stem (%/ppm)	Root (%/ppm)
Total Nitrogen (N)	1.21 ± 0.05	1.00 ± 0.04	2.12 ± 0.06
Total Phosphorus (P)	0.28 ± 0.01	0.09 ± 0.01	0.24 ± 0.01
Total Potassium (K)	2.58 ± 0.06	1.08 ± 0.04	1.27 ± 0.03
Calcium (Ca)	1.83 ± 0.04	0.45 ± 0.02	0.23 ± 0.01

Magnesium (Mg)	0.81 ± 0.03	0.14 ± 0.01	0.12 ± 0.01
Sulphur (S)	0.14 ± 0.01	0.71 ± 0.02	0.24 ± 0.01
Iron (Fe) (ppm)	945 ± 0.015	203 ± 0.06	394 ± 0.01
Manganese (Mn) (ppm)	7 ± 0.01	18 ± 0.01	103 ± 0.03
Zinc (Zn) (ppm)	32 ± 0.01	9 ± 0.01	32 ± 0.01
Copper (Cu) (ppm)	41 ± 0.01	46 ± 0.01	134 ± 0.03
Sodium (Na)	0.35 ± 0.01	0.12 ± 0.01	0.37 ± 0.01
Chloride (Cl)	1.27 ± 0.03	0.63 ± 0.02	0.70 ± 0.02

Table - 4. Composition of elements in leaves, stem and root of *X. strumarium* L. from Pimpali, Baramati, Maharashtra (India).

Parameter	Leaf (%/ppm)	Stem (%/ppm)	Root (%/ppm)
Total Nitrogen (N)	2.16 ± 0.05	2.32 ± 0.06	0.67 ± 0.02
Total Phosphorus (P)	0.32 ± 0.01	0.25 ± 0.01	0.32 ± 0.01
Total Potassium (K)	2.57 ± 0.04	3.62 ± 0.08	1.42 ± 0.03
Calcium (Ca)	2.03 ± 0.05	1.33 ± 0.03	0.15 ± 0.01
Magnesium (Mg)	0.66 ± 0.02	0.53 ± 0.01	0.08 ± 0.01
Sulphur (S)	0.64 ± 0.02	0.69 ± 0.02	0.15 ± 0.01
Iron (Fe) (ppm)	508 ± 0.1	99 ± 0.04	99 ± 0.04
Manganese (Mn) (ppm)	74 ± 0.03	28 ± 0.02	25 ± 0.01
Zinc (Zn) (ppm)	25 ± 0.01	18 ± 0.01	17 ± 0.01
Copper (Cu) (ppm)	22 ± 0.01	31 ± 0.01	29 ± 0.01
Sodium (Na)	0.23 ± 0.01	0.28 ± 0.01	0.37 ± 0.01
Chloride (Cl)	1.15 ± 0.01	2.49 ± 0.04	0.57 ± 0.02

The present investigation evaluated the elemental profile of root, stem, and leaf samples of *Xanthium strumarium* L. collected from Mekhali and Pimpali sites in Baramati Tehsil (Maharashtra). The genus *Xanthium* is widely utilized in traditional herbal medicine, and its therapeutic potential is closely linked to its

phytochemical and elemental constituents. In this study, elements such as Na, P, K, Ca, Mg, Fe, Zn, Mn, Cu, and Cl were quantified using an Atomic Absorption Spectrophotometer and a flame photometer. The results revealed distinct variations in the elemental composition of *X. strumarium* L. collected from the two contrasting

habitats. Notably, Fe accumulation was higher in the leaves of *X. strumarium* L. from the saline habitat (Mekhali) compared to those from the non-saline habitat (Pimpali). Mn concentration was markedly higher in the roots (103 ± 0.003 mg/kg) of plants from Mekhali, whereas in the non-saline habitat, Mn was predominantly accumulated in the leaves (74 ± 0.03 mg/kg), followed by the stem (28 ± 0.02 mg/kg) and roots (25 ± 0.01 mg/kg).

Overall, the comparative assessment of plants from saline (Mekhali) and non-saline (Pimpali) soils of Baramati tehsil indicates that salinity stress significantly influences the elemental distribution in the leaves, stems, and roots of *X. strumarium* L. This study highlights the ecological impact of soil salinity on nutrient uptake and elemental homeostasis in this medicinally important species.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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