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Research Article

Phytochemical and Elemental Profiling of *Sterculia Urens* Roxb. Gum Collected from Different Agro-Ecological Zones of India

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Abstract

Sterculia urens Roxb. (Family: Sterculiaceae), popularly known as Katira or Gum Karaya, is widely used in traditional systems of medicine for its cooling, soothing, anti-inflammatory, and hemostatic properties. The present study aimed to evaluate the influence of diverse agro-ecological zones on the phytochemical and elemental composition of *Sterculia urens* gum collected from five different regions of India—Bilaspur (Chhattisgarh), Karauli (Rajasthan), Guntur (Andhra Pradesh), Sheopur (Madhya Pradesh), and Jhansi (Uttar Pradesh). The samples were subjected to physical evaluation, preliminary phytochemical screening, ATR-FTIR analysis, HPLC profiling, HRAMS analysis, and microwave plasma atomic emission spectroscopy (MP-AES) for elemental profiling. Physical characteristics were uniform across all samples. Phytochemical screening revealed the presence of carbohydrates, tannins, phenolics, and fats. ATR-FTIR confirmed characteristic polysaccharide functional groups with minor regional variations. HPLC identified major compounds such as D-galactose, L-rhamnose, D-galacturonic acid, Sterculinine I, caffeic acid, and sterculinic acid. HRAMS detected 365–430 compounds with 117 common metabolites across all zones, while Jhansi samples showed the highest unique chemical diversity. MP-AES revealed the presence of essential elements such as potassium, sodium, magnesium, and zinc with heavy metals within permissible limits. The study confirms that agro-ecological conditions significantly influence the phytochemical and elemental composition of *Sterculia urens* gum, which may impact its pharmacological and industrial utility.

Keywords: *Sterculia urens*, Katira, Agro-ecological zones, Phytochemical profiling, HRAMS, MP-AES, ATR-FTIR

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Introduction

India possesses one of the richest repositories of medicinal plants in the world, supporting several traditional systems of healthcare including Ayurveda, Siddha, and Unani. Among the diverse medicinal flora, *Sterculia urens* Roxb., commonly known as Indian tragacanth¹, Karaya gum tree, Katira, or Kullu, is an economically and therapeutically important medicinal tree. The gum exudate of *S. urens* is widely used as a cooling, soothing, stabilizing, and bulk-forming agent in traditional medicine and modern pharmaceutical industries².

Traditionally, Katira is employed in the management of cough, throat disorders, burning sensation, hemorrhagic conditions, and bowel irregularities³. Pharmacologically, it acts as a bulk laxative, denture adhesive, thickener, emulsifier, and stabilizer². Climatic stress, soil nutrients, temperature, rainfall, and other agro-ecological factors are known to influence the biosynthesis of secondary metabolites in medicinal plants⁴. However, systematic evaluation of the effect of agro-ecological zones on the chemical profile of *S. urens* gum remains limited.

The present investigation was therefore designed to evaluate the physical, phytochemical, spectroscopic, chromatographic, metabolomic, and elemental characteristics of *Sterculia urens* gum collected from five distinct agro-ecological zones of India.

Materials and methods:

The soil and gum of *Sterculia urens* Roxb. were gathered from G-1 in Bilaspur, Chhattisgarh, and G-2 in Rahir, Karauli, Rajasthan. India's G-3 is from Guntur, Andhra Pradesh; G-4 is from Goras, Sheopur, Madhya Pradesh; and G-5 is from Jhansi, Uttar Pradesh. The Department of Dravya Guna, Faculty of Ayurveda, IMS, BHU's lab conducted the preliminary phytochemical and physical analysis. The BHU Department of Physics conducted an ATR study of *Sterculia urens* gum. The Department of Pharmaceutical Engineering Technology at IIT, BHU, Varanasi, performed the HPLC analysis. *Sterculia urens* Roxb alcohol was analyzed using HRAMS at SATHI, BHU, Varanasi. The Indian Institute of Technology Roorkee conducted the MP-AES of alcoholic *Sterculia urens* Roxb. Soil analysis was done in the lab of the

Department of Agronomy, Institute of Agriculture Sciences BHU.

Geographical Distribution-or Habitat

Sterculia urens Roxb., a deciduous tree native to the Indian subcontinent, is sometimes referred to as the Indian Kulu or Karaya tree⁵. It flourishes in a variety of environments throughout India and its neighbours. The *Sterculia urens* tree can be found in several locations of India, including the Deccan Peninsula, North India, and Central India⁶. Bangladesh, Sri Lanka, and several parts of Southeast Asia are also home to it. It usually thrives in tropical and subtropical regions with sandy or loamy soils that drain well. These trees require elevations up to around 1,000 meters above sea level and are typically found in forests, pastures, and occasionally semi-arid areas. It is found on dry slopes in Garhwal, Bundelkhand, Bihar, Orissa, Bengal, Central India, Deccan, Western Peninsula, and Tamil Nadu⁷, as well as in the outer forest ranges of Shivalak, particularly on stony hills⁷.

Botanical Morphology

A large, soft-wooded tree with fibrous interior and white, papery outer bark. Deciduous leaves have five lobes and an upright trunk. The leaves are 9–12 inches long, broad, rounded, with a cordate base, full, acuminate lobes, and a 6–9-inch petiole. The blooms are tiny, reddish-brown, whitish-brown, and light brown, and the panicle is dense and terminal. This results in a gum that is marketed under the brand name Katira. Santhals consume burdock and administer it for throat conditions. It is called Kullu in Chitrakoot, and its bark is inhaled. According to Hooker (1875) and Singh (1955), its gum might be referred to as the representative material of the actual foreign Tragacanth.

Collection and purification:

Sterculia trees exude following tape of the trunks. The dry season is when harvesting takes place. Before selection, large lumps are broken up into smaller pieces to eliminate the largest bark contaminants. The color (pale yellow to brown) and impurities (BFOM concentration) are used to grade the raw gum (Hamburg, 2014).

Classification of Gum:

Classification of Gums		
Category	Type	Examples
Natural Gums	Seaweed gum	Agar, Algin, Carrageenan, Laminaran
	Plant exudates	Acacia, Tragacanth, Karaya, Ghatti
	Seed gums	Guar gum, Isabgol, Tamarind, Locust bean gum
	Plant extracts	Pectin, Larch, Arabinogalactan
	Animal extract	Chitin
Prepared Gums	Biosynthetic gums	Xanthan, Scleroglucan, Dextrans
	Starch derivatives	Dextrins
	Cellulose derivatives	—

Table 1. Carbohydrates and derived products-

Name of the drug & synonym	Biological source	Constituents	Uses
Gum Karaya	<i>Sterculia urens</i> (Sterculiaceae)	Polysaccharides contain 8% acetyl and 37% uronic acid residues and no methoxyl group.	Thickening agent, emulgent.

Properties of *Sterculia urens*- (As per Bhavaprakasha Nighantu)

Roxb. *Sterculia urens*. Traditional uses include Raktapradar (~metrorrhagia), throat problems, and Kasa (~cough). (Chunekaret al., 2010). In water, it swells between 60 and 100 times. It works well as a bulk laxative since the body cannot digest or absorb it. Additionally, it serves as an emulsifier, thickener, and stabilizer in medications and denture adhesive. Karaya gum is widely used in foods including ice pops, cheese spread, sherbets, and ground meat products because it is listed in the Food Chemical Codex. The paper and textile

industries also use it. India exported Karaya gum valued at ₹675 lac in 1995–1996 and 894 lacs in 1996–1997.

Collection and authentication of *Sterculia urens* gum:

[*Sterculia urens* (Roxb.)] The Katira The gum was gathered in India from G-1 in Bilaspur, Chhattisgarh; G-2 in Rahir, Karauli, Rajasthan; G-3 in Guntur, Andhra Pradesh; G-4 in Goras, Sheopur, Madhya Pradesh; and G-5 in Jhansi, Uttar Pradesh. The plant's legitimacy was verified by the Department of Dravyaguna.

Table 2. Average climate parameters of the individual districts of the selected Agro-ecological zones

Districts	Temp. (Max.) °C	Temp. (Min.) °C	Rainfall (mm)	Av. Relative humidity (%)	Sunshine hour
Bilaspur, CG	41.0	8.0	1165.65	47.65	10.71
Karauli, Rajasthan	49.0	2.0	709.45	38.32	8.28
Guntur, AP	48.47	14.0	913.65	67.32	10.67
Sheopur, MP	42.13	7.4	944	32.07	9.01
Jhansi, UP	41.35	4.0	901.08	41.91	8.86

The average climate parameters of a few districts from different agro-ecological zones are shown in the table. Extreme variance is evident in Karauli, Rajasthan, which has the highest maximum temperature (49°C) and the lowest minimum temperature (2°C). The highest yearly rainfall (1,165.65 mm) and most number of sunlight hours (10.71) are recorded in Bilaspur, Chhattisgarh. Guntur, Andhra Pradesh, has a mild climate with a

minimum temperature of 14°C and the maximum relative humidity (67.32%). While Jhansi, Uttar Pradesh, has a temperate climate, Sheopur, Madhya Pradesh, with comparatively low humidity (32.07%) and 944 mm of rainfall. These differences show how different agroclimatic conditions impact farming methods and crop adaptability in different areas.

Table 3. Agro-ecological zones soil nutrient tests of different districts:

Districts	N (kg/ha)	P (kg/ha)	K (kg/ha)	Fe (kg/ha)	Zn (kg/ha)	pH	EC (ds/m)	OC (%)	BD (g/cc)
Bilaspur, CG	183.96	13.62	245.72	1.28	1.07	6.12	0.19	0.85	1.12
Karauli, Rajasthan	235.76	16.27	175.98	1.10	1.49	7.61	0.46	0.52	1.27
Guntur, AP	216.04	55.21	436.95	11.45	0.34	7.36	0.26	0.39	1.34
Sheopur, MP	202.26	20.01	390.13	10.27	1	7.68	0.36	0.60	1.21
Jhansi, UP	255.73	19.64	213.15	18.13	2.77	7.74	0.22	0.31	1.39

EC- Electrical conductivity, OC-Soil organic carbon, BD-Bulk density

The soil nutrient status of various districts from distinct agro-ecological zones reveals significant variability in nutrient availability, pH levels, organic content and physical properties. The following is a comparative analysis of macro and micronutrients, soil reaction, and other key indicators: The soil nutrient profile varies significantly across districts due to their geographical

and agro-ecological differences. Bilaspur is rich in organic matter but low in nutrients. Karauli, Rajasthan and Sheopur, Madhya Pradesh, exhibit balanced fertility. Guntur, Andhra Pradesh, has nutrient-rich but compact and zinc-deficient soils. Jhansi, Uttar Pradesh, excels in nitrogen and micronutrients but lacks organic carbon and has high bulk density. Such data is crucial for tailoring location-specific soil fertility management and crop planning.

Fig. 1: Climate Data

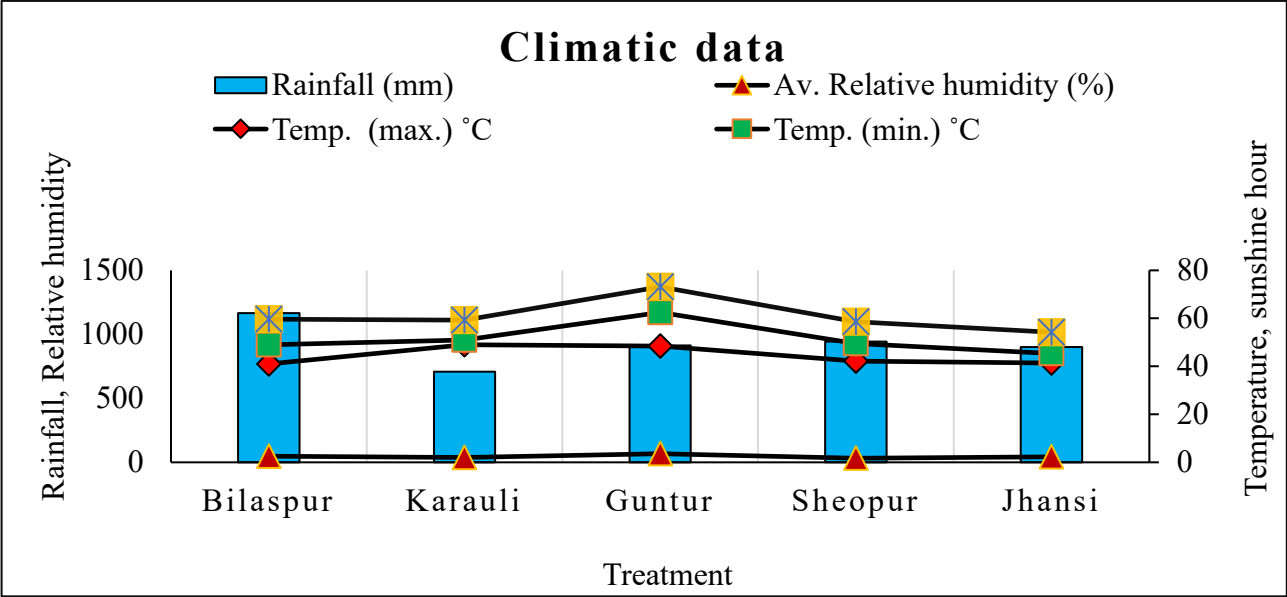


Table 4: Physical Evaluation for different samples

S. N.	Characteristics	Bilaspur G-1	Karauli G-2	Guntur G-3	Sheopur G-4	Jhansi G-5	Physical evaluation
1	Pale yellow or Brown	+	+	+	+	+	
2	Odourless	+	+	+	+	+	
3	Tasteless	+	+	+	+	+	
4	Tears of flakes	+	+	+	+	+	
5	Partly soluble in water,swells, and insoluble in alcohol	+	+	+	+	+	
6	The gum is translucent,transverse, with longitudinal ridges. Fracture is short.	+	+	+	+	+	

Gum samples taken from five distinct agro-ecological zones—Bilaspur (G-1), Karauli (G-2), Guntur (G-3), Sheopur (G-4), and Jhansi (G-5)—show a high degree of consistency in their physical attributes. Pale yellow or brown coloration, odorlessness and tastelessness, tears or flakes, partial solubility in water with swelling and insolubility in alcohol, and typical gum morphology—

translucent with longitudinal ridges and a brief fracture—were common characteristics shared by all samples. These recurring characteristics support their identify as natural gums with similar physical characteristics across geographical areas and suggest a similar botanical origin.

Table 5: Phytochemical Screening:

S.No.	Chemical Test	Samples				
		Sample G-1	Sample G-2	Sample G-3	Sample G-4	Sample G-5
1.	Test for Carbohydrates	+	+	+	+	+
2.	Tests for Alkaloids	-	-	-	-	-
3.	Test for Glycosides	-	-	-	-	-
4.	Test for Flavonoids	-	-	-	-	-
5.	Test for Tannins &Phenolic Compounds	+	+	+	+	+
6.	Tests for Volatile Oils	-	-	-	-	-
7.	Test for Proteins	-	-	-	-	-
8.	Test for Amino acids	-	-	-	-	-
9.	Tests for Fats & Oils	+	+	+	+	+
10.	Test for Steroids	-	-	-	-	-

Alcoholic extracts of *Sterculia urens* Roxb. gum (Samples G-1 to G-5) were subjected to phytochemical screening, which revealed that all of the samples included lipids and oils, tannins and phenolic compounds, and carbohydrates. These components may have antioxidant and nutritional qualities. All of the examined samples, however, lacked alkaloids,

glycosides, flavonoids, volatile oils, proteins, amino acids, and steroids, suggesting a narrow range of secondary metabolites in the alcoholic extract. This selective presence raises the possibility that the gum is more suited for particular industrial or therapeutic uses than for general medical use.

Table 6 : Showing General band assignments of the ATR spectra of alcoholic extract of *Sterculia urens* Roxb. Gum(G-1, G-2, G-3, G-4,G-5)

Peak positions in wave number (cm ⁻¹)					Assignments
Alcoholic extract					
G-1	G-2	G-3	G-4	G-5	
3314	3310	3334	3298	3280	O-H Stretching (Carboxylic acid groups) S
-	1702	-	-	-	C=O Stretching (carbonyl groups) M
1589	1592	1592	1591	1585	N-H Bending (amino or amide groups) W
1416	1416	1404	1413	1413	C-H Bending (methyl or methylene groups) W
-	1372	-	-	-	O-H Bending (hydroxyl groups) S
1235, 1142	1233, 1144	1235, 1139	1236, 1148	1227, 1144	C-O Stretching (ethers, esters, or alcohols) W
1030	1027	1027	1030	-	Carbon ring in cyclic compound (aromatic rings present) W
-	-	-	-	1005, 770	C-H out of plane deformation (aromatic compounds) W
971, 814	892, 811	704	970, 892	887	C=C Bending (double bonds possibly present in aromatic compounds) M

Alcoholic extracts from gum samples (G-1 to G-5) of *Sterculia urens* Roxb. exhibit distinctive functional groups and structural characteristics that are shared by all regions, according to the ATR-FTIR spectrum analysis. The presence of carboxylic acid groups in all samples is indicated by a broad and strong O-H stretching vibration about 3280–3334 cm⁻¹. Carbonyl stretching (C=O) at 1702 cm⁻¹ in G-2 alone indicates a little amount of chemical heterogeneity in this sample. All samples showed N-H bending (1585–1592 cm⁻¹) and C-H bending (1404–1416 cm⁻¹) bands, indicating

the presence of alkyl and amino groups. Peaks at 1227–1236 and 1139–1148 cm⁻¹ show C-O stretching linked to ethers or alcohols, indicating that the gum is polysaccharide. Bands in the 1005–1030 cm⁻¹ and 704–971 cm⁻¹ areas verify aromatic and cyclic compounds. Overall, the spectrum results show that there are significant structural similarities between the alcoholic extracts of *Sterculia urens* gum from various zones, with slight deviations pointing to potential regional biochemical changes.

Table 7: Hundreds of metabolites were observed by LCMS analysis; however, only a few major Iso-level metabolites such as were confirmed by HPLC.

S. N.	Retent ion time	Compound predicted	Bilaspur, Chhattisgarh, G-1, Area%	Rahir, Karauli, Rajasthan, G-2, Area%	Guntur, Andhra Pradesh G-3, Area%	Goras, Sheopur, Madhya Pradesh, G-4, Area%	Jhansi, Uttar Pradesh, G-5, Area%
1	1.935	D-galactose, L rhamnose, and D-galacturonic acid	15.885	10.596	1.502	15.468	24.051
2	2.604	Sterculinine I	8.239	23.505	9.453	11.530	17.176
3	4.904	Caffeic Acid	4.352	5.106	6.324	7.550	4.462
4	10.516	Sterculynic acid	2.891	2.761	ND	ND	ND

Alcoholic extracts of *Sterculia urens* Roxb. gum from five distinct agro-ecological zones (G-1 to G-5) were subjected to HPLC profiling, which revealed the presence of key bioactive chemicals with varying retention times and concentrations (area%). D-galactose, L-rhamnose, D-galacturonic acid, Sterculinine I, and Caffeic acid are represented by the prominent peaks, which show a consistent presence of phytochemicals in

different quantities throughout different locations. Only G-1 and G-2 were found to contain sterculynic acid, indicating that it is a region-specific occurrence. These results demonstrate the gum's basic chemical consistency as well as regional variations in its phytochemical makeup, which may have an impact on its industrial and medicinal uses.

Table 8: Compounds present in the alcoholic extract of *Sterculia urens* gum and their activity, structure:

S.N.	Compound	Reported activity
1.	D-galactose	Antioxidants ⁹
2.	L-rhamnose	Antibacteria ¹⁰
3.	D-galacturonic acid	Inflammation and increased intestinal permeability ¹¹
4.	Sterculinine I	Not Yet reported
5.	Caffeic acid	1. Bacterial and viral infections ¹² 2. Antioxidant, Anti-inflammatory and Anticarcinogenic activity ¹³
6.	Sterculinic acid	Antiparasite drug ¹⁴

Table 9: List of sample names and their Agro ecological Zone, the total number of Compounds with Area max and the number of common and uncommon Compounds.

S. No.	Samples	Agroecological Zone	Compounds		Number of Common Compounds	Number of uncommon Compounds
			Number	Area Max		
1	G-1	Bilaspur, Chhattisgarh	365	22	117	127
2	G-2	Rahir, Karauli, Rajasthan	403	11	117	108
3	G-3	Guntur, Andhra Pradesh	366	21	117	96
4	G-4	Goras, Sheopur, Madhya Pradesh	387	29	117	98
5	G-5	Jhansi, Uttar Pradesh	430	35	117	153

Comparative phytochemical profiling of alcoholic extracts of *Sterculia urens* gum from five different Agro-ecological Zones (AEZs) shows notable differences in the distribution of common and unusual compounds, the total number of compounds, and their relative abundance:

- The overall number of identified chemicals varied from 365 (G-1) to 430 (G-5), indicating geographical variability in metabolite production; all five samples (G-1 to G-5) had 117 similar molecules, indicating a stable phytochemical core across areas.
- The biggest number of compounds (430) and maximal unusual compounds (153) were found in G-5 (Jhansi,

Uttar Pradesh), indicating considerable regional specificity or environmental influence on secondary metabolism.

- On the other hand, G-2 (Rahir, Rajasthan) featured comparatively less rare compounds (108) and the fewest area-max compounds (11), suggesting a more limited phytochemical profile.

-This analysis suggests that agro-ecological conditions significantly influence the phytochemical diversity in *Sterculia urens* gum, with certain zones like Jhansi and Sheopur showing broader metabolite spectra. These findings are essential for selecting ecotypes with the highest phytochemical yield and therapeutic potential.

Microwave plasma atomic emission spectroscopy (MP-AES)-

Table 10: Showing the Concentration of Elements present in G-1, G- 2, G-3, G-4, and G-5

Element	Concentration of elements (in ppm)				
	G-1	G-2	G-3	G-4	G-5
Zn (213.857 nm)	0.03	0.01±0.00	0.02±0.00	0.04±0.00	0.03±0.00
Cd (228.802 nm)	0.00	0.00	0.00	0.00	0.00
Ca (393.366 nm)	Uncal	Uncal	Uncal	Uncal	Uncal
Fe (371.993 nm)	-0.10±0.00	-0.10±0.00	-0.02 ±0.00	-0.11 ±0.00	-0.09 ±0.00

Cu (324.754 nm)	0.01 ±0.00	0.01 ±0.00	0.00	0.01 ±0.00	0.01 ±0.00
Ni (352.454 nm)	0.07±0.00	0.06±0.00	0.01±0.00	0.07±0.00	0.06±0.00
B (249.772 nm)	0.33 ±0.00	0.31 ±0.01	0.06±0.00	0.27 ±0.01	0.23 ±0.01
Bi (306.772 nm)	0.96±0.02	0.94±0.01	0.95±0.01	0.93±0.02	0.96±0.01
Co (340.512 nm)	0.05 ±0.00	0.04 ±0.00	0.02±0.00	0.05 ±0.00	0.04 ±0.00
Pb (405.781 nm)	0.10±0.00	0.09±0.00	0.03±0.00	0.10±0.00	0.09±0.00
K (766.491 nm)	6.67 ±0.07	1.74±0.00	0.54±0.00	4.95±0.02	5.15±0.01
Mg (285.213 nm)	1.32±0.00	5.16±0.03	0.55±0.00	2.23±0.00	4.78±0.02
Mn (403.076 nm)	0.00	0.00	0.01±0.00	0.00	0.00
Cr (425.433 nm)	0.00	0.00	0.00	0.00	0.00
Al (396.152 nm)	0.00	0.00	0.00	0.00	0.00
Na (588.995 nm)	1.39±0.01	4.72±0.00	0.51±0.01	1.91±0.02	4.41±0.02

The elemental analysis of *Sterculia urens* gum samples (G-1 to G-5) from different agro-ecological zones reveals notable variations in elemental concentration. The MP-AES analysis of the G-1, G-2, G-3, G-4, and G-5 was carried out at IIT, Roorkee.

- **Zinc (Zn)** was detected in all samples, with G-4 showing the highest concentration (0.04 ppm).
- **Cadmium (Cd), Chromium (Cr), Aluminium (Al), and Manganese (Mn)** were either absent or present in negligible amounts, suggesting low or non-toxic levels.
- **Iron (Fe)** showed negative readings across all samples, which could indicate instrumental limitations or interferences.
- **Copper (Cu) and Nickel (Ni)** were present in trace amounts, with Ni being highest in G-1 and G-4 (0.07 ppm).
- **Boron (B)** was relatively higher in G-1 (0.33 ppm), indicating a possible geographical influence.
- **Bismuth (Bi)** was uniformly high across all samples (~0.94–0.96 ppm), suggesting its consistent presence.
- **Cobalt (Co) and Lead (Pb)** were present in small but detectable quantities in all samples, with Pb reaching up to 0.10 ppm in G-1 and G-4.
- **Potassium (K) and Sodium (Na)** showed substantial variation. G-1 had the highest K (6.67 ppm), while G-2 had the highest Na (4.72 ppm).
- **Magnesium (Mg)** was most abundant in G-2 (5.16 ppm) and G-5 (4.78 ppm), possibly indicating soil enrichment in those zones.
- **Calcium (Ca)** could not be quantified due to uncalibrated data.

Overall, the elemental profile highlights regional differences in mineral uptake, with certain elements like Bi, K, Na, and Mg being more abundant and potentially contributing to the gum's phytochemical and therapeutic properties.

Discussion:

ATR spectroscopy successfully identified the characteristic functional groups present in the samples and revealed minor regional variations in their chemical composition across the five study sites. HPLC profiling of *Sterculia urens* gum collected from five agro-ecological zones demonstrated significant variation in secondary metabolites, as reflected by differences in retention times. Important biomarkers, including D-

galactose, L-rhamnose, D-galacturonic acid, Sterculinine I, caffeic acid, and sterculic acid, were detected in differing concentrations. These constituents were then validated using HRMS and UV spectral analysis. The findings underscore the chemical heterogeneity and medicinal significance of the gum from diverse regions, reinforcing its therapeutic potential.

HRAMS evaluation of the alcoholic extracts of *Sterculia urens* gum revealed a broad spectrum of metabolites, with the total number of detected compounds ranging from 433 in G1 to 515 in G5. The twenty most abundant compounds in each zone were identified, demonstrating distinct regional variations in phytochemical composition. Several bioactive constituents, such as erucamide, ethoxyquin, DL-malic acid, and capsidiol, showed zone-specific distribution patterns. These metabolites are known for their antioxidant, anti-inflammatory, neuroprotective, and antimicrobial activities, highlighting the medicinal value of *Sterculia urens* gum across different agro-ecological regions.

Further HRAMS profiling indicated the presence of both shared and unique metabolites among the five agro-ecological zones. Using Excel and Google Colab for data analysis, compound overlap and regional specificity were established. Sample G-5 (Jhansi) exhibited the greatest chemical diversity with 430 total compounds, of which 153 were unique, followed by G-2, G-4, G-3, and G-1. A total of 117 compounds were common to all samples, while each region displayed its own distinct phytochemical signature, emphasizing the influence of local environmental factors on the chemical profile of *Sterculia urens* gum.

MP-AES, a highly sensitive technique capable of detecting elements at parts-per-million levels, was employed to assess the elemental composition of the gum samples. The analysis revealed variable concentrations of essential elements such as potassium (present in the highest amount), sodium, magnesium, and zinc across the five samples. Toxic heavy metals, including cadmium, were not detected, and lead levels were well within permissible API limits, confirming the safety of the samples. MP-AES effectively differentiated nutritional and potentially harmful elements, demonstrating its usefulness in evaluating both the health benefits and environmental safety of plant-derived materials.

Conclusion:

The integrated analytical approaches—ATR, HPLC, HRAMS, and MP-AES—effectively revealed the phytochemical and elemental diversity of *Sterculia urens* gum across five agro-ecological zones. ATR confirmed functional groups with slight regional variations. HPLC identified key secondary metabolites, confirmed by HRMS and UV spectra. HRAMS detected 433–515 compounds per zone, including zone-specific bioactive compounds with antioxidant, antimicrobial, and neuroprotective properties. G-5 showed the highest chemical diversity. MP-AES revealed varied elemental profiles, with essential elements like potassium and zinc, and heavy metals within safe limits. These findings underscore the gum's medicinal potential and environmental safety, shaped by regional agro-ecological influences.

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