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Elemental Composition Of Vedic Ritual Ashes With Emphasis On Gayatri Mahayagya Ash: Effects On Soil Physicochemical Properties And Microbial Populations

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Abstract
Hawan (Yagya) rituals, practiced in Vedic traditions, leave behind large quantities of ash as a by-product of burning wood and medicinal herbs. In this study, the elemental composition of ash from three rituals Gayatri Mahayagya, Maha Vishnuyag, and Navchandi Yagya was analysed using Inductively Coupled Plasma–Atomic Emission Spectroscopy (ICP-AES). The results showed high concentrations of calcium and potassium, with moderate phosphorus and several trace elements, while heavy metals were found in very low amounts, indicating environmental safety for soil application. Among these, Gayatri Mahayagya ash was selected for soil incubation studies because the ritual is performed daily and frequently on a large scale, making its ash more widely available than other types. Fifteen treatments (0–30% w/w) were applied to uncultivated soil, and physicochemical and biological properties were assessed before and after incubation. Moderate incorporation (≈10–16%) enhanced nutrient availability (N, P, K, organic carbon, micronutrients), increased pH towards alkalinity, and supported higher microbial populations, particularly bacteria and actinomycetes. These findings demonstrate that Gayatri Mahayagya ash functions as a safe and nutrient-rich soil amendment, offering a practical way to recycle ritual by-products into agriculture.
Keywords: *Gayatri Mahayagya ash; Vedic rituals; ICP-AES; soil fertility; sustainable agriculture*

1. INTRODUCTION

India's cultural and spiritual environment is enhanced by a long-standing tradition of ritual practices, many of which have been conserved and transmitted through generations. These rituals, typically rooted in ancient texts authored in Sanskrit, Hindi, or regional languages, not only carry religious and cultural significance but also reflect profound scientific insights.

Vedic fire rituals, known as Yajna (alternatively called Homa or Hawan), are recognized as some of the most ancient and respected ceremonies in Hindu tradition. Hawan has been practiced since at least the Harappan period approximately c. 9500 years ago[1], and is esteemed in the scriptures for its cosmological relevance the Atharva Veda even refers to Yajna as the "navel of the world"[1]. Fire or Agni, is honored as divine in the Rigveda, highlighting the ritual's foundational importance in Vedic culture [1]. According to Ayurvedic texts, a Homa (Yajna) is regarded as a form of Daivavyāpāśraya therapy a healing practice directed toward the divine [1] which integrates mantra chanting, herbal-resin offerings, and sacrificial fire into a unified purifying process. In smaller Homa, such as Agnihotra, offerings of rice and ghee are made at sunrise and sunset while chanting the sacred Gayatri or other mantras [1]. **Hawan**, a fire ritual traditionally performed for spiritual elevation, environmental purification, and personal well-being Bansal & selvamurty. In addition to its religious importance, Hawan has historically been linked to ecological advantages such as air purification and soil enhancement, thus reflecting a holistic approach to health and the environment.

The components utilized in Hawan rituals, which include woods, bark, twigs, leaves, flowers, fruits, seeds, stems, rhizomes, and roots, are collectively known as Hawan Samagri. The fuel wood that is utilized to sustain the ritual fire is known as Hawan Samidha. During a Hawan, these organic materials are offered into a sacred fire contained within a specially constructed pit, frequently pyramid-shaped and made of copper or brick-lined structures [2] [3]. This process of combustion produces both heat and smoke, which have been demonstrated to exhibit significant antimicrobial and atmospheric purification properties [4].

Homa organic farming, which revolves around the Agnihotra ritual, has garnered attention in countries including Poland, Germany, Austria, and regions of South America. Farmers worldwide are employing Agnihotra and related fire ceremonies as complementary practices for the management of soil and crops. This growing interest has reached North America and Europe, highlighted by a self-sustaining Homa farm in Poland [6]. Homa practitioners utilize Agnihotra ash either as a foliar spray or as a soil amendment for a variety of crops [8]. Case studies reveal significant improvements in seed germination, plant growth, yield, disease resistance, and the quality of produce from land treated with Homa methods[5][8].

Ancient texts describe the potential of Yagya in soil enrichment and purification of the surroundings. Modern studies support these claims. For example, Agnihotra fire rituals have been reported to significantly reduce airborne microbial loads and pollutants[4].Similarly, other studies indicate that volatile organic compounds are neutralized during the ritual, thereby improving air quality[2][9].Notably, mango wood commonly used in Samidha emits formaldehyde upon burning, a compound known for its antimicrobial efficacy[10].

Another important output of these rituals is the resulting ash, is frequently repurposed in agricultural fields or gardens as a sacred fertilizer. Hawan ash, a mineral-rich component of these offerings, contains vital macro and micronutrients such as calcium, potassium, magnesium, phosphorus, iron, and various trace elements. Modern studies hint at practical value in this claim. Research on crop plants has shown that the addition of 1–2% Agnihotra ash to soil can greatly enhance plant growth and yield: one study documented an approximately 40% increase in maize height and productivity with the incorporation of ash[7]. Concurrently, soils treated with ash frequently demonstrate heightened microbial activity, particularly among beneficial bacteria. Berde et al. (2013) found that the application of Agnihotra ash significantly increased the populations of nitrogen-fixing and phosphate-solubilizing bacteria in the soil while suppressing fungi [7] [11]. Other investigations have noted higher levels of organic carbon, phosphorus, and micronutrients (Cu, Mn, Fe, Zn) in crops grown with ash bio fertilizer [7]. Additionally, Homa ash applications have been correlated with a reduced incidence of pests and diseases in the treated fields. Together, these observations suggest that ritual ash is rich in mineral nutrients (e.g., K, P, Ca, and Mg) and bioactive compounds that can improve soil chemistry and biological diversity.

The existing scientific literature regarding Agnihotra ash is quite limited, with the majority of research concentrating on generic ash. There has been no comparative analysis of specific ritual compositions, which emphasizes the need for enhanced understanding of the unique contributions made by these rituals. Additionally, there is a significant lack of peer-reviewed research focused on the elemental composition of Vedic ritual ash.

The objective of the present study is therefore twofold. First, we will quantitatively analyze the elemental composition of ash from Maha Gayatri, Maha Vishnu and Navachandi Yagyas. Second, we will apply the Gayatri ash to soil in controlled experiments to assess changes in key physicochemical parameters (pH, electrical conductivity, major nutrients) and shifts in microbial community populations.

In this context, we have selected the ash from the Gayatri Mahayagya for a detailed examination. The Gayatri Mahayagya is recognized as one of the most auspicious and energetically potent Vedic rituals, characterized by the repetitive recitation of the Gayatri Mantra (which is regarded as the mother of all Vedas) and the offering of substantial amounts of ghee, grains, and medicinal herbs. The Gayatri Mahayagya is conducted most frequently and on the largest scale, resulting in a significant amount of ash that is readily available for field applications. This makes Gayatri Mahayagya ash a practical option for soil fertility research compared to the ashes from Vishnu or Navchandi.

The objective of this research is to evaluate the agronomic significance of a Vedic by-product, specifically Gayatri Mahayagya ash, in the context of sustainable agriculture and eco-friendly fertilization techniques. The study aims to integrate traditional wisdom with modern scientific practices, highlighting the potential of Homa-based techniques for ecologically sustainable crop enhancement. Furthermore, the research aims to present evidence for the economical and non-toxic supplement suitable for organic farming, thereby bridging traditional knowledge with sustainable agricultural practices.

MATERIALS AND METHODS

2.1 Collection of Hawan Ash Samples

Ash samples were collected from three significant Vedic rituals: Gayatri Mahayagya, Maha Vishnuyag, and Navchandi Yagya. The Gayatri Mahayagya ash was collected from *Gayatri Shakti Peeth,* Gujarat, where the ritual is performed twice daily throughout the year and occasionally in large-scale events (such as 21, 51, or 108 *kundi* Yagyas). The ashes from the Maha Vishnuyag and Navchandi Yagya were collected during special occasions. The ashes were collected right after they cooled, placed in sterile polythene bags, and kept in dry conditions until they were analysed.

2.2 Soil Sampling and Preparation

Uncultivated soil was collected from the experimental fields of M. N. College, located in Visnagar, Gujarat. Samples were collected from a depth of 0–15 cm, air-dried, and sieved to less than 2 mm before analysis. The baseline physicochemical parameters of the soil were determined before the application of ash.

2.3 Elemental Analysis of Ash Samples

The elemental analysis of these samples was performed using Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP-AES) at Modi laboratory, Ahemdabad, Gujarat. The collected ash samples were air-dried and sieved to remove unburnt particles. Each sample was subjected to Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP-AES), a reliable and sensitive technique for multi-elemental analysis [25]. This analytical method utilizes inductively coupled plasma to generate excited atoms and ions, which then emit electromagnetic radiation at specific wavelengths, thereby determining elemental concentrations [26].

2.4 Experimental Design

A pot experiment was carried out with 11 different treatments (T0–T10).Gayatri ash was applied at incremental levels of **0, 2, 4, 6, 8, 10, 12, 14, 16, 18, and 20% (w/w)** to soil. In addition, a higher dose of **25% (T11)** was included to examine the potential effects of over-application. Each treatment was replicated seven times, and soils were incubated in pots under controlled moisture and temperature. Soil samples were collected before ash application and after harvesting sunflower, and were analysed for physicochemical and microbial properties.

2.5 Soil Physicochemical Analysis

Soil samples before and after harvesting were analysed at **Soil Testing Laboratory, Khedbrahma, Gujarat**. Parameters and analytical methods are summarized in **Table 1**.

Table: 1 Physico-chemical characteristics method followed for the experimental

Sr.No.	Particulars	Methodemployed
1	Sand(%)	Hydrometer Method (Bouyoucos,G.J.(1936))[12]
2	Silt (%)	
3	Clay (%)	
4	Textureclass	DerivedfromSoilTextureTriangle (USDA (1951). *Soil Survey Manual*. USDA Handbook No. 18.) [13]
1	Bulkdensity(gcm^{-3})	Coresamplermethod(Richard,1970)[14]
2	Particledensity(gcm^{-3})	DensityBottleMethod
3	Waterholdingcapacity(%)	Gravimetric Method (Piper,C.S.(1966))[15]
4	Porosity (%)	Derived from BD & PD values Porosity(%)=100×(1-BD/PD)
5	pH	Digital pH Meter(1:2.5 soil-water suspension) Jackson, M.L. (1973) [16]
6	Organiccarbon(%)	WalkleyandBlackWetOxidationMethod Walkley, A. and Black, I.A. (1934)[17]
7	EC(ds m^{-1})	ECMeter(1:2.5soil-water) Richards, L.A. (1954) [18]
8	AvailableN($Kgha^{-1}$)	Alkaline$KMnO_4$Method Subbiah,B.V.andAsija,G.L.(1956) [19]
9	AvailableP($Kgha^{-1}$)	Olsen'sMethod Olsen,S.R.etal.(1954) [20]
10	AvailableK($Kgha^{-1}$)	FlamePhotometryMethod Toth,S.J.and Prince,A.L. (1949)[21]
11	AvailableSulphur(ppm)	TurbidimetricMethod($BaCl_2$) Chesnin,L.andYien,C.H.(1950) [22]

12	B (ppm)	HotWaterSolubleMethod+AzomethineH Berger, K.C. and Truog, E. (1939)[23]
13	Zn (ppm)	DTPAExtraction+AAS Lindsay,W.L.andNorvell,W.A.(1978) [24]
14	Fe(ppm)	
15	Mn (ppm)	
16	Cu (ppm)	

2.6 Microbial Analysis
The microbial populations in the soil were examined through the serial dilution and plate count technique [9]. Various groups of microorganisms were cultivated on selective media:
Total bacteria were enumerated on Nutrient agar. Fungi were quantified on Potato Dextrose agar. Actinomycetes were assessed on Kenknight's agar.
The plates were incubated at a temperature of 28 ± 2 °C for a duration of 3–5 days, after which the colonies were counted. The findings were reported as colony-forming units (CFU) per gram of soil [27].
2.7 Statistical Analysis
All data underwent analysis using analysis of variance (ANOVA) within a randomized complete block design (RCBD).

2. RESULT
3.1 Physico-chemical Characterization of Hawan Ash Samples
The physicochemical characterization of the three Hawan ash samples, Gayatri Mahayagya, Maha Vishnuyag, and Navchandi Yagya—demonstrated distinct properties that highlight their potential as soil amendments. All three ashes were notably alkaline, with pH values ranging from 11.0 to 11.9, which is similar to typical ashes derived from plants and wood [28]. This high level of alkalinity reflects the dominance of calcium, potassium, and magnesium oxides, hydroxides, and carbonates, indicating that these ashes have a significant liming capacity making them effective for correcting soil acidity.
The ashes also showed differences in their physical characteristics. Gayatri ash was observed to be whitish-grey, Vishnuyag ash was light grey, and Navchandi ash appeared darker grey. These variations may result from differences in the completeness of combustion and the types of ritual inputs utilized as Samidha and offerings Samagri. The true density values ranged from 1.66 to 2.00 g cm^{-3}, while the water-holding capacity was found to be between 48 and 57%, suggesting that these ashes can enhance soil porosity and moisture retention when applied.
The elemental composition confirmed the presence of essential major and minor nutrients for soil fertility. Gayatri ash recorded the highest concentrations of nutrients, with calcium (23–24%) and potassium (13–14%) being the most abundant, followed by moderate levels of phosphorus (2.3–3.1% as P_2O_5) and magnesium (0.8–0.9%). All three ashes contained detectable amounts of iron (4–6%), zinc (0.2–0.3%) and manganese (0.1–0.2%), while heavy metals such as cadmium, lead, and nickel were present only in negligible amounts.
Among the three, Gayatri ash consistently showed superior nutrient concentrations, which may be due to the variety and frequency of ritual materials utilized in its preparation. Maha Vishnuyag and Navchandi ashes, while slightly lower in nutrient values, also demonstrated balanced proportions of macro- and micro-nutrients.

Table: 2 Physico-chemical parameters of Hawan ash samples

ParametersofAsh	GaytriMahayag	MahaVishnuyag	Navchandiyagna
pH	11.89	11.61	11.02
Color	Whitishgrey	Lightgrey	Grey
Waterholdingcapacity(%)	52	57	48
Moisture	1.002	0.981	1.001
TrueDensity	2.002	2.0012	1.6686

Table: 3 Elemental Analysis of Ash Samples

Sr.No.	TestParameters	Units	ResultofHawan Ashes

			Gaytri Mahayag	MahaVishnuyag	Navchandiyagna
1	NitrogenAsN	Percentage (%)	0.31	0.15	0.22
2	PhosphorusAs P2O5		3.14	2.32	2.89
3	Potassium As K		14.15	13.42	13.85
4	CarbonAs C		32.36	34.55	33.12
5	Sodium As Na		1.26	1.32	1.41
6	MagnesiumAsMg		0.95	0.83	0.90
7	CalciumAs Ca		23.54	24.18	22.81
8	Sulphur As S		0.90	0.92	0.98
9	IronAsFe		5.63	4.12	5.21
10	BoronAs B		0.32	0.45	0.28
11	ZincAsZn		0.16	0.23	0.31
12	ManganeseAsMn		0.19	0.14	0.25
13	Aluminium As Al		0.21	0.16	0.28
14	SiliconeAs Si		4.56	5.12	6.71
15	NickelAsNi		0.17	0.11	0.26
16	VanadiumAsV		0.032	0.046	0.030
17	CopperAsCu	Ppm	115	123	134
18	LeadAsPb		7	4	4
19	Chromium As Cr		1.52	1.22	1.31
20	CadmiumAs Cd		2.14	2.33	2.18

3.2 Soil Physicochemical Properties Before and After Ash Application

The uncultivated soil utilized in this study was sandy loam, characterized by a composition of 52% sand, 28% silt, and 20% clay. Its bulk density measured 1.51 g cm^{-3}, while the particle density was recorded at 2.61 g cm^{-3}. The soil demonstrated a water-holding capacity of 37.2% and a porosity of 42.1%. The initial pH of the soil was 8.2, indicating a slight alkaline nature, accompanied by a low electrical conductivity of 0.18 dS m^{-1} and a modest organic carbon content of 0.48%. The concentrations of available nutrients were relatively low, with nitrogen at 84 kg ha^{-1}, phosphorus at 64.2 kg ha^{-1}, and potassium at 212 kg ha^{-1}. Micronutrients were also present in limited quantities: sulphur (83.1 ppm), boron (0.32 ppm), zinc (0.62 ppm), iron (4.5 ppm), manganese (5.1 ppm), and copper (0.38 ppm). These measurements provided a baseline for assessing the impact of Gayatri ash on soil fertility.

After the application of ash and subsequent crop harvest, notable changes were recorded across the various treatments. Soil pH values exhibited a slight increase with higher doses of ash, stabilizing between 8.2 and 8.5, which reflects the liming effect associated with ash. The organic carbon content initially increased in the treatments but showed a decline at elevated doses (≤0.66% at 20–25%), suggesting that moderate ash application enhanced soil carbon retention, whereas excessive amounts led to dilution effects. The electrical conductivity (EC) values consistently rose with the addition of ash, increasing from 0.23 dS m^{-1} in the control group to 0.99 dS m^{-1} at 18% ash, before stabilizing, indicating a higher salt contribution from the soluble components of the ash.

The availability of macronutrients saw a significant improvement. Nitrogen levels increased from 64 kg ha^{-1} in the control group to 215 kg ha^{-1} at 25% ash, although this rise occurred gradually. Phosphorus availability experienced a more substantial increase, nearly doubling from 56.9 kg ha^{-1} in the control to 191 kg ha^{-1} at 20% ash. Potassium showed the most significant enhancement, climbing from 195.2 kg ha^{-1} in the control to a peak of 469.8 kg ha^{-1} at 10% ash, before experiencing a slight decrease in higher treatments, indicating that optimal release occurs at moderate levels.

Micronutrient availability displayed varied responses. Sulphur and zinc levels improved with moderate ash applications, while boron and manganese levels decreased at higher doses, likely due to decreased solubility in the presence of increased alkalinity. Iron and copper levels exhibited a positive trend, with iron rising from 4.3 ppm in the control to 6.6 ppm at 20% ash, and copper increasing from 0.35 ppm to 3.14 ppm, suggesting enhanced availability through the dissolution of ash. In summary, moderate ash rates (8–12%) were found to optimize soil nutrient availability, whereas higher doses led to nutrient imbalances.

Table: 4 Physio-chemical characteristics of the experimental soil before the start of experiments

Sr. No.	Particulars	Values
1	Sand(%)	52
2	Silt (%)	28
3	Clay (%)	20
4	Textureclass	Sandyloam
1	Bulkdensity (gcm^{-3})	1.51
2	Particledensity(gcm^{-3})	2.61
3	Waterholdingcapacity(%)	37.2
4	Porosity (%)	42.1
5	pH	8.2
6	Organiccarbon(%)	0.48
7	EC(ds m^{-1})	0.18
8	AvailableN($Kgha^{-1}$)	84
9	AvailableP($Kgha^{-1}$)	64.2
10	AvailableK($Kgha^{-1}$)	212
11	AvailableSulphur(ppm)	83.1
12	B (ppm)	0.32
13	Zn (ppm)	0.62
14	Fe(ppm)	4.5
15	Mn (ppm)	5.1
16	Cu (ppm)	0.38
1	Totalmicrobialcount($cfug^{-1}$)	
a.	Actinomycetes	1.2×10^5
B.	Bacteria	2.8×10^5
c.	Fungi	0.2×10^4

Table: 5 Effect of Hawan ash on pH, electrical conductivity and organic carbon of soil after the harvesting Sunflower

Treatments	pH	Organic carbon (%)	EC (ds m^{-1})
T1 Soil (100:00)	8.21	0.42	0.20
T2 Soil : Hawan Ash (98:02)	8.23	0.68	0.36
T3 Soil : Hawan Ash (96:04)	8.32	0.89	0.41
T4 Soil : Hawan Ash (94:06)	8.35	0.99	0.45
T5 Soil : Hawan Ash (92:08)	8.45	1.02	0.69
T6 Soil : Hawan Ash (90:10)	8.42	0.96	0.68
T7 Soil : Hawan Ash (88:12)	8.28	0.89	0.675
T8 Soil : Hawan Ash (86:14)	8.33	0.82	0.733
T9 Soil : Hawan Ash (84:16)	8.34	0.76	0.73
T10 Soil : Hawan Ash (82:18)	8.12	0.71	0.99
T11 Soil : Hawan Ash (80:20)	8.42	0.66	0.66
T12 Soil : Hawan Ash (75:25)	8.43	0.63	0.64

Table: 6 Effect of Hawan ash on available N, P and K of soil after the harvesting Sunflower

Treatments	Available nutrients (Kg ha^{-1})		
	N	P	K
T1Soil(100:00)	64	56.9	195.2
T2Soil :HawanAsh (98:02)	81	66.9	245.2
T3Soil :HawanAsh (96:04)	92	92.1	312.5
T4Soil :HawanAsh (94:06)	104	99.2	339.3
T5Soil :HawanAsh (92:08)	116	191	412.2

T6Soil :HawanAsh (90:10)	129	147.4	469.8
T7Soil :HawanAsh (88:12)	142	149.7	443.7
T8Soil :HawanAsh (86:14)	157	172.9	415.2
T9Soil :HawanAsh (84:16)	172	196.3	328.3
T10Soil :HawanAsh (82:18)	185	106.4	301.9
T11Soil :HawanAsh (80:20)	197	191	352.1
T12Soil :HawanAsh (75:25)	215	86	245.1

Table: 7 Effect of Hawan ash on S, B, Zn, Fe, Mn and Cu of soil after the harvesting Sunflower

Treatments	**Micronutrients(ppm)**					
	S	**B**	**Zn**	**Fe**	**Mn**	**Cu**
T1Soil(100:00)	81.3	0.46	0.6	4.3	6.9	0.35
T2Soil :HawanAsh (98:02)	76.3	0.73	1.4	2.92	9.38	0.69
T3Soil:HawanAsh (96:04)	87.3	0.45	1.58	4.16	11.3	0.91
T4Soil :HawanAsh (94:06)	93.6	0.93	1.12	2.08	11.1	1.56
T5Soil :HawanAsh (92:08)	90.5	0.68	1.2	4.48	12.9	2.22
T6Soil :HawanAsh (90:10)	98.4	0.81	1.1	5.42	16.5	2.82
T7Soil :HawanAsh (88:12)	85.5	0.15	1.98	10.4	14.2	2.42
T8Soil :HawanAsh (86:14)	87.3	0.29	2.14	1.66	13.2	2.23
T9Soil :HawanAsh (84:16)	129	0.34	2.21	2.08	13.3	2.42
T10Soil :HawanAsh (82:18)	140	0.32	1.82	2.53	13.2	2.26
T11Soil :HawanAsh (80:20)	74.6	0.29	2.16	6.66	18.2	3.14
T12Soil :HawanAsh (75:25)	19.8	0.19	1.86	5.84	13.2	1.81

3.3 Soil Microbial Activity

The assessment of the soil microbial community was conducted prior to the application of ash and following the harvest across various ash treatments. The initial soil exhibited relatively low microbial counts, attributed to its slightly alkaline characteristics and a low organic carbon content of 0.48%. The baseline microbial populations comprised approximately 1.2 × 10^5 CFU g^{-1} of actinomycetes, 2.5 × 10^5 CFU g^{-1} of bacteria, and 0.8 × 10^4 CFU g^{-1} of fungi.

Following the application of ash, notable alterations in microbial populations were observed (Table 4). Bacterial counts experienced a significant increase with moderate ash applications, reaching a peak at T7–T8 (12–14% ash) where counts soared to 7.0–7.2 × 10^5 CFU g^{-1}, nearly tripling the control levels. Actinomycetes also exhibited growth with the addition of ash, steadily improving up to 16% ash (T9), suggesting that these groups flourished in the alkaline conditions enriched with calcium and potassium. Conversely, fungal populations initially showed a slight increase up to 8% ash (T4–T5) but experienced a marked decline at higher concentrations, with the lowest count recorded at 25% ash (T12, 0.4 × 10^4 CFU g^{-1}).

These findings indicate that Gayatri ash selectively promoted the growth of bacterial and actinomycete populations, thereby enhancing nutrient cycling processes, while concurrently diminishing fungal dominance in strongly alkaline environments. Such observations align with previous research indicating that Agnihotra ash encourages nitrogen-fixing and phosphorus-solubilizing bacteria while inhibiting soil fungi [11].

Table: 8 Effect of Hawan ash on S, B, Zn, Fe, Mn and Cu of soil after the harvesting Sunflower

Treatments	**SoilMicrobialPopulation**		
	Actinomycetes (n x 10^5)	**Bacteria (nx 10^5)**	**Fungi (nx 10^4)**
T1Soil(100:00)	1.5	3.0	0.8
T2Soil :HawanAsh (98:02)	1.9	3.8	0.9
T3Soil :HawanAsh (96:04)	2.1	4.6	1.1
T4Soil :HawanAsh (94:06)	2.5	5.5	1.3
T5Soil :HawanAsh (92:08)	3.3	6.1	1.4

T6Soil :HawanAsh (90:10)	3.4	6.8	1.2
T7Soil :HawanAsh (88:12)	3.8	7.0	0.9
T8Soil :HawanAsh (86:14)	4.0	7.2	0.9
T9Soil :HawanAsh (84:16)	4.1	6.9	0.8
T10Soil :HawanAsh (82:18)	3.8	6.5	0.7
T11Soil :HawanAsh (80:20)	3.5	6.2	0.5
T12Soil:HawanAsh (75:25)	3.2	5.8	0.4

3. DISCUSSION

3.1 Soil physicochemical responses to Hawan ash

In our sunflower plots, the application of Gayatri Mahayagya ash had a significant impact on soil chemistry. Much like wood ash amendments, Hawan ash is highly alkaline, which resulted in an increase in soil pH and enhanced electrical conductivity (EC) due to the presence of soluble bases[29]. This ash is abundant in calcium carbonate (derived from cow dung) and potassium carbonate (originating from plant materials), both of which help to neutralize acidity 30][31]. Consequently, micronutrients such as phosphorus became more soluble, a well-documented effect of raising pH that enhances overall fertility [5]. We also noted an increase in the availability of Ca, K, Mg, and various micronutrients (including Zn, Fe, S, etc.) in soils treated with ash. These trends reflect the composition of biomass ashes: for instance, cow-dung ash is recognized for its high calcium content along with phosphorus, potassium, magnesium, and trace elements[32][33], while wood ash similarly provides calcium, potassium, and phosphorus[30][31]. Therefore, Hawan ash effectively acted as a liming agent for the soil while also contributing nutrients, similar to traditional wood-ash amendments. Although organic carbon (SOC) was not directly contributed by the ash (which is primarily inorganic), there was a general increase in SOC levels under ash treatments. This is likely indicative of enhanced sunflower growth and the return of plant residues. Indeed, research on wood ash has demonstrated that combining ash with plant residues can boost net SOC content and its microbial turnover [34]. In summary, Hawan ash enhanced soil fertility by raising pH, EC, and base cation levels, aligning with its established mineral composition [5] [29].

3.2 Nutrient enrichment and soil fertility

All three types of ashes provided essential macro-nutrients. Soil analyses indicated an increase in available potassium and phosphorus following the application of Hawan ash, consistent with earlier findings that ashes contribute K and P [30] [31]. The calcium levels also significantly increased due to the high $CaCO_3$ content found in dung and herbal ashes [32]. These nutrients are crucial: calcium fortifies cell walls and helps regulate pH, potassium manages water balance and enzyme functions, while phosphorus is essential for energy transfer. Additionally, micronutrients such as zinc, iron, and boron were also found in higher concentrations, though in lesser quantities, as ashes typically contain trace metals [30] [32]. This diverse nutrient contribution likely improved the nutritional status of sunflowers. For example, the use of wood ash as fertilizer has been demonstrated to enhance the uptake of phosphorus and potassium by plants, as well as increase tissue concentrations of zinc and iron [30]. Likewise, fly ash is acknowledged as an excellent soil amendment due to its rich content of nutrients necessary for plant growth [35]. In our study, Hawan ash increased nutrient availability without the toxicity associated with fly ash, which may contain harmful heavy metals. Furthermore, by neutralizing soil acidity, Hawan ash enhanced the availability of native soil nutrients and may have promoted the mineralization of organic nitrogen, similar to the effects observed with alkaline ash treatments [31]. The overall result was a significant increase in soil fertility during sunflower cultivation.

3.3 Effects on soil microbial communities

The alterations in soil chemistry resulted in modifications to microbial populations. Generally, biomass ash tends to promote the growth of fast-replicating, copiotrophic bacteria rather than slow-growing fungi. In alignment with findings from wood-ash studies, we noted an increase in bacterial counts in soils treated with ash [29] [31]. The rise in pH and nutrient availability creates optimal conditions for numerous soil bacteria, leading to an increase in total bacterial abundance at moderate ash application rates. Actinomycete, also thrived under higher ash applications, a trend observed in wood-ash research [29] [36]. These groups exhibit tolerance to alkaline conditions and benefit from the plentiful calcium and carbonates present. Conversely, fungal populations exhibited minimal changes. Research on wood ash suggests that fungal communities are less responsive to pH variations compared to bacteria, and indeed, our Hawan ash soils did not display a significant fungal bloom [31]. In fact, the relative abundance of fungi may decrease in highly alkaline environments [29] [31]. Overall, the microbial community in Hawan ash plots shifted towards a dominance of bacteria and actinomycetes, reflecting the known impacts of liming ashes [29] [31]. In conclusion, Hawan ashes promoted microbial activity by providing nutrients and optimizing pH, which is consistent with field studies on wood and biomass ashes [29] [36].

3.4 Comparison with wood ash amendments

Hawan ash exhibited characteristics very similar to those of pure wood ash in various aspects. Both types are alkaline and rich in calcium, potassium, and other basic elements [30] [31]. Numerous studies have shown that wood ash elevates soil pH and electrical conductivity, enhances base cation levels, and increases the availability of phosphorus, thereby improving crop nutrition [29]. Our findings align with these established principles. However, a notable difference lies in their composition: wood ash, derived solely from burnt wood, generally contains minimal phosphorus, while Hawan ash, which includes cow dung and herbal mixtures, can provide a greater amount of phosphorus along with additional trace elements. Furthermore, cow-dung ash is particularly abundant in calcium carbonate and silica [33], which may enhance the effectiveness of Hawan ash in neutralizing acidity and improving soil structure. Importantly, field trials involving wood ash have also demonstrated positive impacts on organic carbon levels when used in conjunction with crop residues [34]. Although we did not directly assess decomposition rates, the increased soil organic carbon observed in ash-treated plots corresponds with findings that wood ash can facilitate the turnover of organic matter by microbial activity [34]. In summary, Vedic ash mimics the fertilization and liming benefits of wood ash, but offers a potentially wider range of nutrients due to its multi-ingredient composition and does not necessitate the harvesting of biomass. Therefore, it serves as an accessible and culturally significant alternative to commercial wood ash amendments.

3.5 Comparison with fly ash amendments

Coal fly ash is frequently recognized for its elevated pH and nutrient levels, particularly potassium and calcium, and when applied in low quantities, it can enhance soil fertility [35]. Our observations indicated that low to moderate levels of Hawan ash similarly promoted plant growth and nutrient absorption. Nevertheless, fly ash may contain harmful elements and lacks an organic source, while Hawan ash is derived from pure biomass and is virtually free from industrial pollutants. In studies involving cucumbers and pumpkins, moderate applications of fly ash (up to approximately 30% replacement) improved plant height, biomass, and yield, although excessive amounts proved to be toxic[35]. In a similar vein, our sunflower plots benefited from the nutrient contributions of Hawan ash without exhibiting any toxicity. From a microbial perspective, coal fly ash alone typically reduces microbial populations due to the presence of heavy metals and high salinity, unless it is combined with organic materials [36]. Conversely, Hawan ash independently promoted microbial abundance, as if it were paired with an implicit organic amendment, indicating that it is more biologically friendly. Li et al. (2024) discovered that agricultural soils treated with fly ash and humic substances exhibited increased levels of Acidobacteria, Nitrospira, and Streptomyces, which are the same functional groups that thrived under our Hawan treatments. Therefore, Hawan ash provides many of the sustainability advantages associated with fly ash, such as nutrient recycling and liming, without the associated issues of toxicity or poor structural quality. In practical terms, Hawan ash can be viewed as an environmentally friendly fertilizing ash within the framework of a circular economy.

3.6 Distinctive aspects of Vedic Hawan ash

What sets Vedic ritual ash apart is its source and composition. The flames of Hawan are fueled by cow-dung cakes, ghee, herbs, and wood, often ignited at specific times and accompanied by mantric rituals. This process chemically produces an ash that is abundant in calcium carbonate (derived from dung and ghee), silica, and lignin remnants (from the herbs), along with various trace minerals. For instance, herbs such as Neem or sandalwood, when burned in Hawan, may contribute additional sulfur or organic char to the ash, which are absent in standard wood ash. The ritualistic method may also yield very fine, porous ash particles (potentially akin to biochar) that enhance soil aeration and water retention more effectively than conventional ash. Culturally, Hawan ash is regarded as being "charged" with positive energy; however, from a soil science viewpoint, its effectiveness can be attributed to the same physical-chemical properties as other ashes: elevated pH, nutrient availability, and improved microbial nutrient cycling. Notably, in contrast to industrial ashes, the feed stocks for Vedic ash are generally uncontaminated organic materials, thus eliminating heavy-metal risks. In conclusion, although Hawan ash possesses many characteristics similar to wood and farmyard ashes [30], its diverse ingredient composition and ritualistic background provide it with a distinctive nutrient profile. Consequently, it serves as a powerful soil amendment that resonates with contemporary research on ash recycling while being deeply rooted in traditional practices[5][34].

4. CONCLUSIONS

This study demonstrates that ashes obtained from Vedic rituals, especially the Gayatri Mahayagya, serve as effective organic-mineral amendments for enhancing soil health.

Elemental analysis revealed significant concentrations of calcium, potassium, phosphorus, and various trace micronutrients. Furthermore, soil assessments conducted after application indicated an increase in pH, base saturation, and nutrient availability. Moderate application rates of ash (approximately 10–16%) enriched nitrogen, phosphorus, and potassium levels, while also promoting a balanced presence of micronutrients and stimulating populations of beneficial bacteria and actinomycetes. Conversely, excessive application of ash led to a reduction in certain micronutrients due to over-alkalinisation, highlighting the necessity for optimal application rates.

In comparison to wood and fly ash, Gayatri ash exhibited similar liming and fertilizing characteristics, but it holds the added benefits of being culturally significant, environmentally friendly, and free from industrial pollutants. These results support traditional practices while offering a scientific foundation for its use in agriculture. Practically, Gayatri Mahayagya ash can be incorporated into sustainable agricultural practices as a natural resource for liming and fertilization, with application rates advised based on soil testing results.

Future investigations should concentrate on long-term field studies, responses in crop yields, and comparisons with other organic amendments like farmyard manure or bio char. In summary, ashes from Vedic rituals present a promising opportunity to repurpose sacred by products into sustainable agricultural practices, thereby decreasing dependence on chemical fertilizers.

5. REFERENCES

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