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RESEARCH ARTICLE

Physicochemical Analysis of Plant Ash, Characterisation of *Havan* Ash and its Application

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Abstract

Background: Three plants, Samidha *Mangifera indica, Cedrus deodara, Pinus roxburghii,* leaves of *Azadirachta indica, Ficus religiosa, Bacopa monnieri, Bougainvillaea glabra,* root of *Hemidesmus indicus,* bark of *Terminalia arjuna,* herbal *agarbatti* and *Havan samagri* were used for ashing in a muffle furnace at 673°C. **Aim:** The study is based on characterisation and physicochemical analysis of Plant ash, *Havan* ash and the impact of plant germination and growth. **Methods:** These eleven plants were further studied for their physicochemical properties and for the detection of nine elements, namely Na, Ca, Mg, K, P, Fe, Ni, Cu, and Zn, using ICP-MS. Characterisation of *Havan* ash was done by GC-MS and FE-SEM analysis. **Results:** Fatty acid methyl esters were the major compounds detected in the ethanolic Havan ash extract, which plays a significant role in antimicrobial activity, biodiesel production, and as a component in paints, inks, and plastics, as well as serving as a raw material for surfactant use. The FE-SEM image of *Havan* ash reveals particles with intricate, irregular shapes, large internal surface area, and elongated and dumbbell-shaped particles. Further studies based on the application of *Havan* ash, deodar wood ash, pinus wood ash and their effect on *Jaun* seedling germination and growth as compared to a control pot (100% soil). **Conclusion:** *Havan* ash is characterised by long, dumbbell-shaped particles and an extremely porous structure with a bulky interior surface area. Its physicochemical characteristics point to possible uses in water purification technologies, cosmetics, and industrial operations. However, because the material's physical and chemical properties are still not well understood, more research is required to develop effective recycling techniques.

Major Findings: Ash is a useful amendment in agricultural applications because of its important qualities, which include moisture retention and swelling capacity, which affect soil permeability.

Keywords: Ashing, Characterisation, Mineral Element, Seed Germination

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1. Introduction

The mineral by-product of burning organic molecules is called ash. Three million tonnes of wood ash were generated in the United States, with over 70% of that amount going to landfills[1]. Different plant materials have different capacities for producing ash. White oak, yellow poplar, douglas fir bark, and white oak bark had ash percentages of 0.45%, 0.43%, 1.64% and 0.87% respectively, analysis of other wood species[2]. Beech wood has an ash percentage of 0.58%, and the ash level of various African wood species ranged from 1.25 to 8.80%[3,4]. The plants and soil in which the plants are grown all affect the composition of ashes. Another crucial element that affects a plant material's ash output is the temperature at which it burns[2]. The presence of black particles, or burnt wood particles, in the ashes is usually a sign of incomplete combustion. Depending on the particle size or kind of plant material, burning at higher temperatures (often not surpassing 600 °C) may speed up and assurance full combustion. Weight loss and the breakdown of some inorganic components can occur when plant materials are burned at higher temperatures[2]. In ash, solubility is determined by the amount of alkali metal components and other soluble salts (like K and Na sulphates and chlorides), and is influenced by the kind of plant material that is burned. The first fire-based method, dating back to the ancient Vedic texts, is the *Havan*. *Havan*, which is beneficial to both nature and living things, is the process of eliminating poisonous conditions from the environment using the energy that comes from fire[5]. The ash generated during *Havan* performance has several uses in the fields of agriculture, environmental pollution prevention, medicine, etc[6,7]. *Havan* ash has new applications in the water purification process since it regulates the parameters of water quality[8,9]. Yagya ash and fumes are useful for agriculture, air and water cleaning, reducing bacterial pathogenicity, and improving the health of living organisms. *Havan* ash can lower the pathogenicity of microorganisms, which helps to prevent infections[10]. The use of *Havan* ash accelerates the antifungal effect by controlling soil-borne pathogens and reducing the formation of hyphae[11]. Bud length in relation to seed weight[12] shows that adding *Havan* ash to rice seeds increases germination from the primary stage. The amount of soluble phosphate in soil increases when *Havan* ash is added[13]. *Haven* ash provides nutrients to mushrooms during their growth when it is applied to the straw substrate[14]. *Havan* ash added to the yellow soil boosts the Zea mays crop output by regulating the growth of the maize crop[15]. According to *in vivo* trials conducted on human fingers for physical injuries and domestic cats' ears for infections (otitis), using *Havan* ash as an exterior ointment is a new way to aid in the healing of wounds[10]. The ash of *Havan* generated by executing it at precise sunrise/sunset times while chanting mantras and using the proper raw ingredients contains a variety of micronutrients and macronutrients to produce a variety of beneficial effects. In the present investigation, the physiochemical studies of various plant ashes, characterisation studies of *Havan* ash, and considering the encouraging outcomes of the ash generated following *Havan yajna* in the previously mentioned publications for agricultural applications, environmental cleaning elements, and medicinal significance, its use in jaun seedling germination and growth is recommended. The goal of the current study is based on the physicochemical analysis of plant ash, the characterisation of *Havan* ash, and its application.

2. Materials and Methods

2.1 Preparation of Ash

Three plants, Samidha *Mangifera indica, Cedrus deodara* and *Pinus roxburghii,* leaves of *Azadirachta indica, Ficus religiosa, Bacopa monnieri* and *Bougainvillaea glabra,* root of *Hemidesmus indicus,* bark of *Terminalia arjuna,* herbal *agarbatti* and *Havan* samagri were collected from Gurukula Kangri (Deemed to be University), Haridwar. These plant materials were oven-dried at 150°C to a constant weight. The dried plant materials were then ground into fine powder by using a domestic grinder and used for dry ashing. Pre-cleaned silica crucible was heated at 600°C until the weight of the crucible was constant[16]. A silica crucible containing 20 grams of each powdered plant material was heated to 673°C in a muffle furnace until no smoke was produced. After an hour, the crucible was removed and allowed to cool at room temperature in desiccators. After cooling, ash of eleven plant samples was collected in separate plastic bottles and marked for further physicochemical and elemental detection analysis[17].

2.2 Physical State

The physical state of the matter is an important parameter. The ash sample was shown as a fine powder. The colour of each plant ash was greyish white, brown, dark blackish or blackish, and the taste of all the ash samples was orally tasted.

2.3 Moisture Content

In order to determine the moisture content, 5 grams of the ash samples were dried at 110°C in an electric oven until they reached a consistent weight. In order to determine the percentage of moisture content, the weight difference was used as a gauge[18].

Moisture content = Weight of sample taken – Weight of sample after drying

$$Percentage\ of\ moisture\ content = \frac{Weight\ of\ sample\ after\ drying}{Weight\ of\ the\ sample\ taken} \times 100$$

2.4 Ash Content

The amount of ash was measured by weighing 5 grams of the plant sample in a silicon crucible that had been previously weighed and heated to 600°C and then cooled. Before being cooked for three to five hours in a 600°C muffle furnace, the crucible was first heated over a low flame until all of the material was thoroughly charred. It was then weighed after cooling. Consequently, this was done until the weight remained constant and the ash turned nearly white or greyish white[19].

$$Percentage\ of\ ash\ content = \frac{Weight\ of\ ash}{Weight\ of\ sample} \times 100$$

Ash Value

The plant ash was directly dissolved in solvents, boiled and filtered by using Whatmann ashless filter paper and then ignited at 600°C, cooled, and the weight showed the insolubility[20].

$$Percentage\ of\ soluble\ ash = \frac{Weight\ of\ ash\ after\ drying}{Weight\ of\ ash} \times 100$$

2.5 Determination of Alcohol Soluble Ash

50 mg of oven-dried ash, 50 ml of alcohol, and five minutes of water bath heating were combined in a beaker to determine the amount of alcohol-soluble ash. After passing through a Whatman filter paper 42 that had been previously weighed and cleaned three times with hot alcohol, the filter paper that contained the residue was burned in an oven set to 80 to 90 degrees Celsius. Heated and cooled until a constant weight was obtained. The initial weight of ash was deducted from the weight of insoluble ash. Using the dried ash as a reference, the proportion of alcohol-soluble ash was determined.

Weight of soluble ash = Weight of ash taken – Weight of insoluble ash

$$Percentage\ of\ alcohol\ soluble\ ash = \frac{Weight\ of\ alcohol\ soluble\ ash}{Weight\ of\ ash\ taken} \times 100$$

2.6 Determination of Water-soluble Ash

For the determination of water-soluble ash, 50 mg of oven-dried ash was taken in a beaker and 50 ml of boiled or double-distilled water and heated on a water bath for five minutes. Filtered through previously weighed Whatman filter paper 42 and washed three times with hot double-distilled water. The residue was dried at 100-105 °C for one hour in an oven. It was heated and cooled until the weight remained constant. The initial weight of ash was deducted from the weight of insoluble ash. Using the dried ash as a reference, the proportion of water-soluble ash was determined[20].

Weight of soluble ash = Weight of ash taken – Weight of insoluble ash

$$Percentage\ of\ water-soluble\ ash = \frac{Weight\ of\ water-soluble\ ash}{Weight\ of\ ash\ taken} \times 100$$

2.7 Determination of Acid-Soluble Ash

For the determination of acid-soluble ash, 50 mg of oven-dried ash was taken in a beaker and 50 mL of diluent. Hydrochloric acid and heated in a water bath for 5 minutes. Filtered through previously weighed Whatman filter paper and washed three times with hot dil. Hydrochloric acid. The residue was dried at 110°C for one hour in an oven. Heating and cooling were done until a constant weight was obtained. The weight of insoluble ash was subtracted from the weight of ash taken initially. The percentage of acid-soluble ash was calculated with reference to the dried ash[21].

Weight of soluble ash = Weight of ash taken – Weight of insoluble ash

$$Percentage\ of\ acid-soluble\ ash = \frac{Weight\ of\ acid-soluble\ ash}{Weight\ of\ ash\ taken} \times 100$$

2.8 Hydrogen Ion Potential (pH)

pH is defined as the hydrogen ion activity or concentration of a given sample. It gives a clear idea of the relative acidity or alkalinity of the sample.

$pH = \log^{10}[H]^{+}$

The pH of a sample can be measured directly with the help of a pH meter[22]. pH was determined by dissolving one gram of ash in 100 mL of double-distilled water. The buffer solutions of a pH meter are obtained by immersing the electrode in a buffer solution of known pH 7 to 10 at a definite temperature. Then the pH of the sample was directly measured by dipping the electrode in the sample[23].

2.9 Analysis of Mineral Elements from Plants and *Havan* Ash by ICP-MS

A total of eleven plant ash samples were collected for analysis of mineral elements by using ICP-MS at Patanjali Food and Herbal Park Pvt. Ltd., Laksar Road, Padartha, Haridwar. A Multiwave 3000 high-pressure microwave digestion machine was used to prepare the sample. For digestion, a solution of strong nitric acid (HNO_3), hydrogen peroxide (H_2O_2), and hydrofluoric acid (HF) was introduced to Teflon jars containing 100–150 mg of precisely weighed ash. To eliminate fluoride residues, 6 mL of a 4% boric acid (H_3BO_3) solution was added in a later stage. An ELAN DRC II Inductively Coupled Plasma Mass Spectrometer (ICP-MS) was then used to do elemental analysis. Radio frequency (RF) power of 1000 W, lens voltage of 5.75 V, plasma gas flow rate of 13 $L{\cdot}min^{-1}$, auxiliary gas flow of 1.2 $L{\cdot}min^{-1}$, and nebuliser gas flow of 0.89 $L{\cdot}min^{-1}$ were the operating conditions for the device. Platinum cones, a Scott-type spray chamber, and a cross-flow nebuliser were used for standard mode measurements. A total of nine elements (Na, Ca, K, P, Mg, Fe, Cu, Ni, Zn) are determined from plants (used in *samidha* and *samagri*), *agrabatti* and *Havan samgri* ash by inductively coupled plasma mass spectrometry[24].

2.10 GC-MS Analysis of *Havan* Ash Sample

10 gm of *Havan* ash sample dissolved in 50 ml ethanol solvent after complete combustion of 100 gm *Havan samagri* raw material inside the muffle furnace at 673℃ for 2 hours. After sample preparation of ethanolic *Havan* ash extract, it was analysed using the GC-MS with AOC-20i Split less Auto injector at Patanjali Food and Herbal Park Pvt. Ltd., Laksar Road, Padartha, Haridwar. The analysis was completed using the experiment parameters of SH-Rxi-5Sil MS (5% biphenyl 95% dimethyl polysiloxane) for a column with 30 m length, 0.25 mm diameter and 0.25 µm film thickness. After that, a 100 mg to 200 mg sample dissolved in Ethanol/Methanol/Ethyl acetate/Hexane (as per solubility) and, if required, further diluted by taking 1 ml to 10 ml solvent and injected into GC-MS[25,26].

2.11 Field Emission Scanning Electron Microscopy (FE-SEM)

The FE-SEM analysis of *Havan* ash and *Havan* raw material (i.e. without burning) sample were performed at PR Testing Services India, Anand Vihar, Uttamnagar, Delhi. The shape, size and surface morphological features at different magnifications of *Havan* ash particles and *Havan* raw material were elucidated with the help of FEI Nova NanoSEM 450 FE-SEM. The 10 kV beam energy was used for FE-SEM analysis[27]. A Field Emission Scanning Electron Microscope (FE-SEM) was used to analyse the materials' surface morphology and characteristics. To stop the samples from charging, they were dried, set on aluminium stubs with conductive carbon tape, and then sputter-coated with a thin layer of gold. Imaging was carried out at an accelerating voltage of 5–15 kV while operating in a high vacuum. High-resolution images were produced by detecting secondary electrons while the electron beam raster-scanned across the sample surface. The range of magnifications was 1000× to over 50,000×, and the spatial resolution was near 1-2 nm. Digital micrographs were gathered for additional morphological examination.

2.12 Effects of *Havan* Ash on Plant Growth and Seed Germination

Soaked *jaun* (*Hordeum vulgare*) seeds were used to investigate how *Havan* ash affected seed germination and plant growth. Four plastic pots were used to allow the seeds to germinate independently. i.e. A- Control pot (100 % Soil + distilled water), B – Treated pot (50 % Soil + 50 % *Havan* ash), C pot- (50 % Soil + 50 % Deodar wood ash), D pot- (50 % Soil + 50 % Pinus wood ash). After 72 hours, the number of seeds that had germinated in each pot was counted. After six days,

the length of the roots and shoots (in centimetres) was measured to assess the impact on plant growth[9].

3. Results and Discussion

3.1 Physicochemical Study of Plant Ash

The various physicochemical data of plants (used in *samidha* and *samagri*), herbal *agarbatti* and *Havan* ash are given in Table 1.

3.1.1 Physical State

The ash of all plants and *Havan* ash was obtained in fine, thin and powdered form.

3.1.2 Colour

The colour of ash was different in each plant due to the presence of various elements. It was observed greyish white in herbal *agarbatti*, Pinus wood and Mango wood, Ash colour observed Greyish brown of *A. indica, H. indicus*, dark blackish in *C. deodara, F. religiosa*, *B. monnieri*, white colour shown *B. glabra*, dark brownish colour was found in *T. arjuna,* and *Havan* ash was light brown in colour.

3.1.3 Taste

Anantmula root and peepal leaves had an alkaline taste when the ash samples were examined orally, whereas the remaining nine samples had a pungent taste (Table 1).

3.2 Moisture Content

The plant ash and *Havan* ash were weighed before drying at 110°C, and then weighed after drying; the difference in the two weight values gives the moisture content (loss of drying). The percentage of moisture content was maximum in *B. glabra* (1.98), followed by *F. religiosa* (1.90), *B. monnieri* (1.67), *Havan* ash (1.61), *T. arjuna* (1.33), *A. indica* (1.20), *C. deodara* (0.98) and minimum in herbal *agarbatti* ash (0.76), followed by *P. roxburghii, H. indicus* (0.77), *M. indica* (0.90) (Table 1).

3.3 Ash Content

The percentage of ash content was maximum in *F. religiosa* (38.79), followed by *M. indica* (17.76), *B. glabra* (14.89), *T. arjuna* (11.09), *C. deodara* (10.89), *A. indica* (10.32), *P. roxburghii* (9.4), *Havan* ash (9.1) and minimum in *H. indicus* (5.91), followed by herbal *agarbatti* ash, *B. monnieri* (8.9) (Table 1).

3.4 Ash Value (Solubility/Insolubility)

The percentage of ash solubility in acid (HCl), water and alcohol soluble ash of the plants was determined. The ash was highly insoluble in water, followed by alcohol and acid and highly soluble in acid, followed by alcohol and water. *Anantmula* root ash is highly soluble in acid 98% and insoluble, 2%, while peepal leaf ash is less soluble in acid 56% and insoluble 44%. However, *Bougainvillaea* leaves ash is highly soluble in alcohol 31% and insoluble in 69%, whereas *Brahmi* leaves ash is less soluble in alcohol 13% and insoluble in 87%. In water solubility, *Bougainvillaea* leaves, Neem leaves, and peepal leaf ash show similar percentages, i.e. 28, while *Brahmi* leaves ash shows the maximum insoluble 89% in water (Table 1). The pH range is between 9.9 to 8.9. Ash value of *Havan samagri* pH is 9.9, while Peepal leaves is 8.9. Taste of ash is pungent except *Anantmula* root, peepal leaves and *Bougainvillaea* leaves (Table 1).

A key physicochemical feature that affects the stability, shelf life, and processing properties of plant materials and the products made from them is moisture content. The observed variance in moisture content across the studied species is in line with earlier research, which states that environmental factors, post-harvest processing techniques, and species-specific anatomical and physiological characteristics all affect moisture levels. Take B, for example. *Gabra and F. religiosa,* which showed the highest moisture content, might have metabolic adaptations or leaf structures that allow them to retain more water than other species. Because water is lost during burning and subsequent processing, ash samples, including *Havan* ash and herbal *agarbatti* ash, demonstrated noticeably decreased moisture content. Thermal treatment causes both bound and free water to evaporate, which significantly lowers the moisture content. This reduction is a well-documented phenomenon in the literature. The various ecological adaptations and water-use efficiency of plant species are also reflected in the variations in moisture content between species. In the food, pharmaceutical, and cosmetic industries, where moisture content directly impacts product quality, microbiological stability, and processing efficiency, this fluctuation has an impact on the choice of raw materials. Moisture content is an important physical and chemical characteristic that influences the stability, shelf life, and processing qualities of plant materials and their products. The differences

Table 1. Physiochemical analysis of selected plant ash and percentage of ash value in alcohol, water and acid

S. NO.	Plant ash	Physical state	Colour of ash	pH of ash value	Taste of ash	% of moisture content	% of ash content	% of ash value					
								Alcohol		Water		Acid	
								Sol	Insol	Sol	Insol	Sol	Insol
1	*Havan samagri*	Fine powder	Light brown	9.9	Pungent	1.61	9.1	24	76	20	80	70	30
2	Pinus wood	Fine powder	Grayish white	9.5	Pungent	0.77	9.4	20	80	20	80	94	6
3	Herbal *agarbatti*	Fine powder	Grayish white	9.8	Pungent	0.76	8.9	20	80	14	86	96	4
4	*Neem* leaves	Fine powder	Grayish brown	9.7	Pungent	1.20	10.32	28	72	28	72	72	28
5	*Anantmula* root	Fine powder	Grayish brown	9.5	Alkaline	0.77	5.91	20	80	18	82	98	2
6	Mango wood	Fine powder	Grayish white	9.2	Pungent	0.90	17.76	21	79	20	80	90	10
7	Peepal leaves	Fine powder	Dark blackish	8.9	Alkaline	1.90	38.79	30	70	28	72	56	44
8	*Deodar* wood	Fine powder	Dark blackish	9.7	Pungent	0.98	10.89	19	81	18	82	89	11
9	*Arjun* bark	Fine powder	Dark brownish	9.0	Pungent	1.33	11.09	16	84	14	86	92	8
10	*Brahmi* leaves	Fine powder	Blackish	9.0	Pungent	1.67	8.9	13	87	11	89	93	7
11	Bougainvillea leaves	Fine powder	Whitish	9.0	Alkaline	1.98	14.89	31	69	28	72	97	3

in moisture content among the species studied match previous research, which shows that environmental factors, post-harvest processing methods, and the specific anatomical and physiological traits of each species all affect moisture levels. For instance, *B. glabra* and *F. religiosa*, which had the highest moisture content, may have adaptations or leaf structures that help them hold onto more water than other species. When materials are burned and processed, they lose water. For example, ash samples like *Havan* ash and herbal *agarbatti* ash showed much lower moisture content. Thermal treatment makes both bound and free water evaporate, leading to a significant decrease in moisture. This reduction is well-documented in existing research. The differences in moisture content among species also reflect their ecological adaptations and how efficiently they use water. In industries such as food, pharmaceuticals, and cosmetics, this variation in moisture content can affect product quality, microbiological stability, and processing efficiency, influencing the choice of raw materials.

3.5 Mineral Elements Analysis

The plant is a rich source of minerals. The inorganic elements or minerals are essential to life because the imbalance of these elements in the body leads to a disease state. A total of nine elements (Na, Mg, Ca, K, P, Fe, Cu, Ni, Zn) are determined from the plants (used in *samidha* and *samagri*), *agarbatti* and *Havan* ash. The concentration of elements and their quantity were determined in ppm (parts per million) and then converted into percentage form (unit % w/w) (Table 2). The maximum concentration of Na was present in the ash of *A. indica* (1.25 %), herbal *agarbatti* (0.96 %), *H. indicus* (0.78 %), followed by *B. monnieri, F. religiosa, B. glabra, Havan samagri, T. arjuna, M. indica, P. roxburghii* and *C. deodara*. The maximum concentration of Ca was present in ash of *A. indica* (21.20 %), *B. monnieri* (20.10 %), *B. glabra* (19.28 %), *T. arjuna* (17.47 %), *P. roxburghii* (16.96 %), herbal *agarbatti* (14.07 %), *M. indica* (6.15 %), *Havan samagri* (3.80 %), followed by *H. indicus, C. deodara*

and *F. religiosa*. The maximum concentration of K was present in ash of herbal *agarbatti* (14.96 %), *B. monnieri* (9.99 %), *A. indica* (9.23 %), *B. glabra* (6.94 %), *Havan samagri* (3.99 %), followed by *M. indica, P. roxburghii, T. arjuna, F. religiosa, H. indicus* and *C. deodara*. The maximum concentration was present in *A. indica* (0.83 %) and the minimum in *C. deodara* (0.02 %). The maximum concentration of Mg was present in the ash of *A. indica* (4.10 %), *H. indicus* (3.77 %), *B. glabra* (3.43 %), followed by *B. monnieri, M. indica, Havan* samagri, herbal *agarbatti*, *T. arjuna, P. roxburghii, F. religiosa and C. deodara*. The maximum concentration of trace element Fe was present in the ash of *B. glabra* (1.90 %) and the minimum in *F. religiosa* (0.02 %). The maximum concentration of trace element Cu was present in the ash of *B. monnieri* (4.56 %), the minimum in *C. deodara* (0.04 %), and nothing was found in *F. religiosa*. The maximum concentration of trace element Ni was present in the ash of *A. indica* (1 %) and the minimum in *F. religiosa* (0.006 %). The maximum concentration of trace element Zn was present in the ash of *H. indicus* (4.17 %) and the minimum in *F. religiosa* (0.01 %). Moderate concentration of all elements, i.e. Na (0.18 %), Ca (3.80 %), K (3.99 %), P (0.60 %), Mg (1.02 %), Fe (0.45 %), Cu (0.12 %), Ni (0.24 %), and Zn (0.34 %) were present in the ash of *Havan samagri*. The range and mean concentration of these nine elements (in ppm) in the plants, *agarbatti* and *Havan* ash were calculated (Table 3).

This observation is consistent with some researchers, who found that the fruit of *C. fistula* had higher potassium levels. *C. fistula* is a noteworthy dietary source of potassium. Diuresis, the reduction of hypertension, and the control of heart rhythm all depend on potassium. The diuretic effects of plant-derived medications may be attributed to the high potassium content of medicinal plants[28,29]. A crucial micronutrient for preventing anaemia and reducing cough related to Angiotensin-Converting Enzyme (ACE) inhibitor medication, iron content in *A. tetracantha* was measured at 0.072%. *A. tetracantha* had the highest phosphorus levels (14.66 mg/kg; 0.001466%), while *A. baccifera* had the lowest. Homeostasis of intracellular fluid, phospholipid structure, and coenzymatic activities (NAD, NADP), especially in ATP and high-energy phosphate molecules, depends on phosphate ions. Phosphorus also promotes calcium phosphate deposition, which aids in bone ossification[30].

The concentrations of sodium and magnesium were lowest in *A. tetracantha* and highest in *M. madarasapatana*. The cellular uptake of glucose and amino acids, as well as energy metabolism, depends on sodium, and *A. tetracantha* has the greatest sodium concentration (0.34%). The fourth most abundant element is magnesium[31].

Ash values are important because they can be used to identify low-quality products, earthy matter. Understanding the amount of ash in a plant helps

Table 2. Mineral elements composition (percentage) in the plants' ash by using Inductively Coupled Plasma Mass Spectrometry (ICP-MS)

S. No.	Plants ash	Na	Ca	K	P	Mg	Fe	Cu	Ni	Zn
1	*Havan samagri*	0.18	3.80	3.99	0.60	1.02	0.45	0.12	0.24	0.34
2	Deodar wood	0.06	0.40	0.27	0.02	0.17	0.07	0.04	0.05	0.12
3	Herbal *agarbatti*	0.96	14.07	14.96	0.26	0.92	0.52	0.54	0.34	0.45
4	Mango wood	0.12	6.15	3.90	0.67	1.08	0.05	0.14	0.08	0.03
5	Pinus wood	0.07	16.96	1.51	0.41	0.75	0.05	0.06	0.06	0.07
6	Arjun chal	0.17	17.47	1.41	0.18	0.80	0.21	0.23	0.02	0.38
7	Neem leaves	1.25	21.20	9.23	0.83	4.10	0.76	0.87	1.00	0.46
8	Peepal leaves	0.32	0.01	0.37	0.08	0.30	0.02	-	0.006	0.01
9	Bougainvillea leaves	0.20	19.28	6.94	0.80	3.43	1.90	0.86	0.98	0.78
10	*Brahmi* leaves	0.45	20.10	9.99	0.61	2.01	0.30	4.56	0.78	0.47
11	*Anantmula* root	0.78	0.86	0.34	0.65	3.77	0.33	0.46	0.46	4.17

***Quantity in percentage (unit %w/w)**

determine its inorganic content. Even while there may not be much of a percentage difference in ash across samples, this nevertheless shows a shift in quality. With substitution, contamination, and adulteration, ash values rise. The presence of sand or soil pollution is indicated by any increase in acid-insoluble ash. Ash that dissolves in water is a sign of depleted material[32].

Acid-insoluble ash was determined to constitute 2.7% of the total ash recovered, which was 9.8% w/w. Determining the moisture content is another crucial factor to consider when evaluating plant medications because inadequate drying can occasionally result in the enzymatic degradation of active ingredients[33]. Both water and volatile matter are measured by this parameter. When plant materials contain too much water, microorganisms grow and deteriorate. The powdered leaf medication's moisture content of 2.3% w/w showed that it had been adequately dried and stored[34].

Havan ash, like other plant ashes, varies in its solubility in alcohol, acid, and water, as well as in its pH, colour, taste, and the elements it contains, such as Na, Ca, K, P, Mg, Fe, Cu, Ni, and Zn. The alkaline character of these ashes is indicated by all of these physicochemical parameters. In the periodic table of elements, potassium and sodium are members of group I, which is distinguished by the creation of soluble salts and bases. Equal amounts of OH^- and H^+ ions are produced when water self-ionises. Additionally, potash ionises into K^+ and CO_{32}^- ions upon introduction. When the CO_{32}^- ion abstracts the H^+ ion from water, the H^+ ion decreases, but the OH^- ion increases, raising the pH (alkaline condition). Due to the alkaline nature of ash, it reduces the acidity of soil and adds beneficial minerals and Trans elements of the d block, i.e. Cu, Ni, Zn, Fe into soil.

Table 3. The range and mean concentration of elements (in ppm) in the plants, *agarbatti* and *Havan* ash

S. No.	Elements	Range in ppm	Mean
1	Na (Sodium)	600.36 – 12544.22	4,196.71
2	Ca (Calcium)	160 – 212038.39	109407.03
3	K (Potassium)	2779.63 – 149600	48151.97
4	P (Phosphorus)	257.50 – 8383.38	4688.58
5	Mg (Magnesium)	1766.97 – 41002.43	16719
6	Fe (Iron)	230 – 19080.87	4304.04
7	Cu (Copper)	456.67 – 45680.17	7218
8	Ni (Nickel)	60 – 10090.54	3720.76
9	Zn (Zinc)	110 – 41789.97	6676.64

3.6 GC-MS Compounds

Table 4 shows the chemical compounds of ethanolic *Havan* ash extract. A total of 10 Phyto-components were identified by GC-MS. The major fatty acid methyl ester compounds with high percentage of peak area - 13-Docosenoic acid, methyl ester (47.04 %), 8,11,14-Docosatrienoic acid, methyl ester (17.47 %), Linoleic acid, methyl ester (14.24 %), Hexadecanoic acid, methyl ester (6.34 %), cis-Methyl 11-eicosenoate

Table 4. Isolated compounds (% peak area, % peak height and retention time) of ethanolic *Havan* ash extract by GC-MS

Peak No.	Name of compound	Molecular Formula	Molecular Weight	Retention Time	Peak Area %	Height %
1	Isopropyl myristate	$C_{17}H_{34}O_2$	270	17.035	2.27	2.58
2	Hexadecanoic acid, methyl ester	$C_{17}H_{34}O_2$	270	18.075	6.34	7.17
3	Linoleic acid, methyl ester	$C_{19}H_{34}O_2$	294	19.691	14.24	14.64
4	8,11,14-Docosatrienoic acid, methyl ester	$C_{23}H_{40}O_2$	348	19.750	17.47	19.19
5	Methyl stearate	$C_{19}H_{38}O_2$	298	19.985	2.46	2.72
6	cis-Methyl 11-eicosenoate	$C_{21}H_{40}O_2$	324	21.518	4.97	5.48
7	13-Docosenoic acid, methyl ester	$C_{23}H_{44}O_2$	352	23.172	47.04	43.35
8	15-Tetracosenoic acid, methyl ester	$C_{25}H_{48}O_2$	380	24.675	1.70	1.74
9	Squalene	$C_{30}H_{50}$	410	25.439	1.46	1.54
10	gamma- Sitosterol	$C_{29}H_{50}O$	414	28.912	2.03	1.59

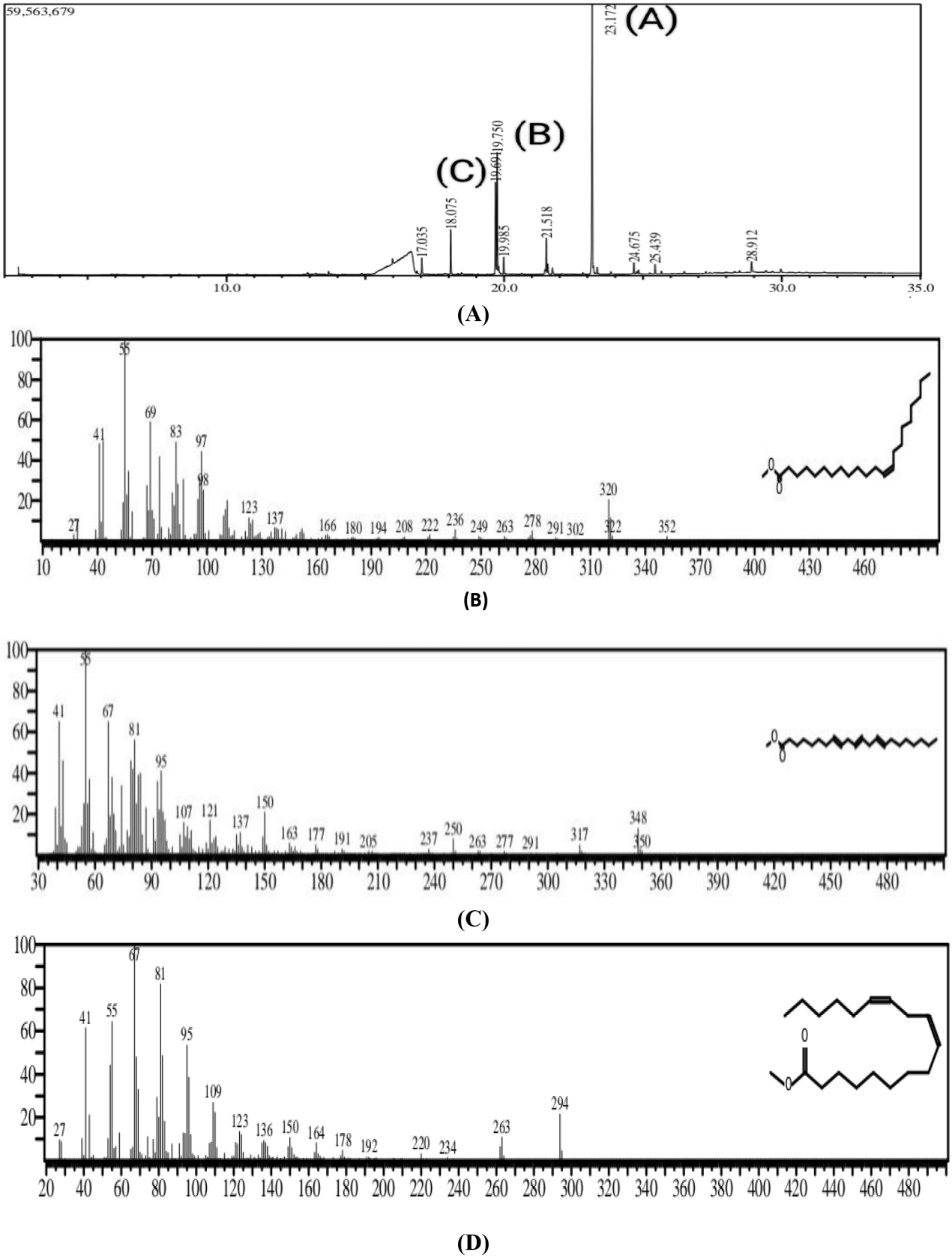


Figure 1. **(A).** Chromatogram of GC-MS analysis of *Havan* ash sample in ethanol solvent.

(4.97 %), Methyl stearate (2.46 %), Isopropyl myristate (2.27 %), 15-Tetracosenoic acid, methyl ester (1.70 %) were detected while major polyunsaturated triterpene hydrocarbon compound Squalene (1.46 %) and naturally occurring plant steroid gamma- Sitosterol (2.03 %) with peak area % were also detected in ethanolic *Havan* ash extract. Figure 1 shows the GC-MS chromatogram of the ethanolic extract of *Havan* ash, isolated major compounds. It appeared that the ethanolic extract of the *Havan* ash sample contains a cluster of fatty acid methyl ester, polyunsaturated triterpene and natural plant steroid compounds at retention time ranges from 17.035 to 28.912.

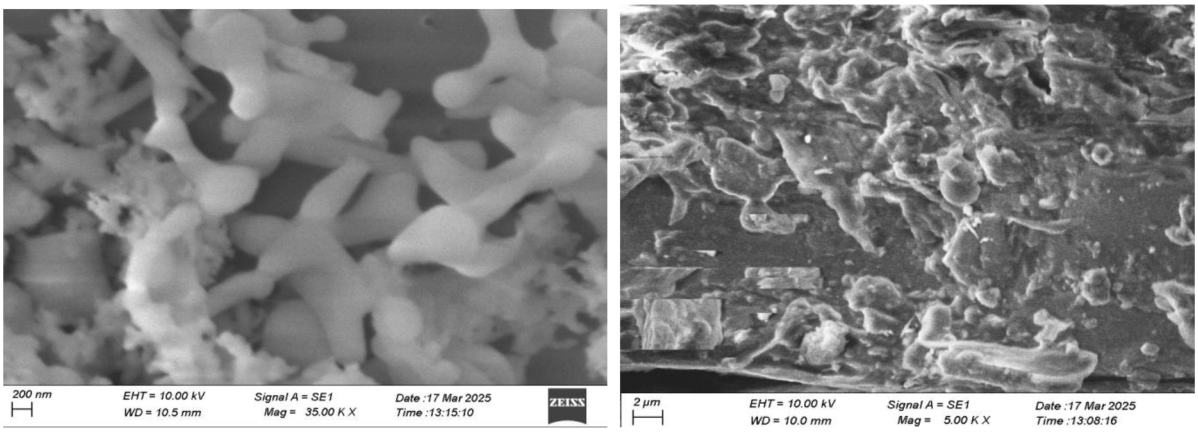
Individual compound spectra with their retention time. **(B).** Mass spectra of compound 13-Docosenoic acid, methyl ester (R. time-23.172). **(C).** Mass spectra of compound 8, 11, 14-Docosatrienoic acid, methyl ester (R. time- 19.750). **(D).** Mass spectra of compound Linoleic acid, methyl ester (R. time – 19.691).

Its historic usage in treating a variety of diseases is supported by the presence of a variety of bioactive chemicals in the Plant. More accurate pharmacological insights would be obtained, meanwhile, by separating distinct phytochemical components and assessing their biological activity. The discovery highlights potential as a candidate for phytopharmaceutical research by confirming the presence of several bioactive chemicals in the plant. Thus, more investigation into its therapeutic uses is necessary[26,35]. Major GC-MS compounds of ethanolic *Havan* ash extract were fatty acid methyl ester detected which has the main role as antimicrobial activity, biodiesel component, paint additive, ink additive, plastic lubricant, and raw material for surfactant use.

3.7 Field Emission Scanning Electron Microscopy (FE-SEM) Analysis of *Havan* Ash

The surface morphology of the *Havan* ash (i.e. burned raw material in the *Havan* experiment) and *Havan* raw material (i.e. without burning) were examined under a scanning electron microscope (Figure 2). The FE-SEM image of *Havan* ash reveals particles with intricate and irregular shapes. The structures appear porous and spongy, with some particles showing elongated, dumbbell-shaped branching forms, while others are more compact and granular. This diversity in shapes suggests a complex microstructure, which could influence the ash's properties and potential applications.

Using FE-SEM to examine the surface morphology of *Havan* ash reveals an intriguing transformational journey: the ritual burning process shapes the raw plant material into a complex microstructure canvas. In contrast to the smooth, well-organised texture of unburned biomass, the ash has a striking appearance: tiny particles with branching, dumbbell-like shapes and irregular, sponge-like shapes contrasted with compact granules. This diverse landscape represents the physical and chemical changes essential to the ash's functional significance and goes beyond simple appearance. *Havan* ash's porous, asymmetrical forms reveal a matrix full of voids and channels that were



(A) **(B)**

Figure 2. Field emission scanning electron microscopy image of **(A).** *Havan* ash, **(B).** *Havan* raw material.

created during combustion by mineral reordering and volatilisation. Because more surface area is available for interactions with other substances, this increased porosity can significantly increase the reactivity of the ash. This means that, in environmental applications, *Havan* ash is far more effective than the raw plant material it was originally made of at adsorbing heavy metals, catalysing reactions, or improving soil structure. In accordance with results from sophisticated SEM analyses on biomass ashes, the presence of different forms—elongated, fibrous, or granular—indicates that the mineral content and crystallinity have changed. *Havan* ash has long been used in ritual and is regarded as a symbol of wellness and purification. This legacy now has a more solid basis thanks to modern science. According to studies that explain how the architecture of plant-derived ash makes it a resource for water filtration, soil enrichment, and environmental protection, the microstructure seen under FE-SEM is directly related to the ash's demonstrated physical and chemical properties. With significant ramifications for sustainability and health, this evidence reframes a cultural artefact as a material that has been scientifically validated[36].

3.8 Effect of *Havan* Ash on Plant Growth and Seed Germination

After six days of seeding, the average shoot and root length of the *Jaun* seedling treated with *Havan* ash were 3.76 cm and 1.27 cm, respectively, while the shoot and root length of the control pot, which was not treated with ash, were 2.55 cm and 0.65 cm, respectively. As compared to the control pot (100 per cent soil), the results indicate that the seedling treated with *Havan* ash grew 32% and 49% longer in both shoot and root length, respectively. The seedling treated with deodar wood ash had average shoot and root lengths of 3.07 cm and 1.09 cm, respectively, while the seedling treated with pinus wood ash had average shoot and root lengths of 3.10 cm and 1.18 cm, respectively. Total average length of seedling in A control pot (100 % soil), B pot (50 % soil + 50 % *Havan* ash), C pot (50 % soil + 50 % deodar wood ash), D pot (50 % soil + 50 % pinus wood ash) was 3.20 cm, 5.03 cm, 4.16 cm and 4.28 cm respectively noted (Table 5). The number of germinated jaun seeds treated with *Havan* ash (19 seeds) was more than that of seeds treated with deodar wood ash (17 seeds) and pinus wood ash (18 seeds) after 72 hours, with 25 sown seeds in each pot. Seed germination increased by 21.06 %, 11.77 % and 16.67 % due to treatment of *Havan* ash, deodar wood ash and pinus wood ash, respectively, as compared to the control pot (Table 5 and Figure 3).

In this research, *Havan* ash has a beneficial effect on jaun seedling germination and growth due to the moderate concentration of mineral elements present in it, as compared to the control pot, deodar and pinus wood ash pot.

Table 5. Effect of *Havan* ash on seed germination and plant growth. The table shows a comparison between *Havan* ash with control (untreated pot), deodar and pinus wood ash

Effect of ash on Plant growth				
***Jaun* seedling length after 6 days (in cm)**	**A-Pot (Control) 100% Soil**	**B-Pot (Treated with 50% Soil + 50% *Havan* ash)**	**C-Pot (Treated with 50% Soil + 50% *Deodar* wood ash)**	**D-pot (Treated with 50% Soil + 50% Pinus wood ash)**
Shoot length	2.55	3.76	3.07	3.10
Root length	0.65	1.27	1.09	1.18
Total average length of the seedling	3.20	5.03	4.16	4.28
Effect of ash on seed germination				
A total of 25 seeds were sown in each pot	**A-Pot (Control) 100% Soil**	**B-Pot (Treated with 50% Soil + 50% *Havan* ash)**	**C-Pot (Treated with 50% Soil + 50% Deodar wood ash)**	**D-Pot (Treated with 50% Soil + 50% Pinus wood ash)**
Total number of germinated seeds after 72 hours	15	19	17	18

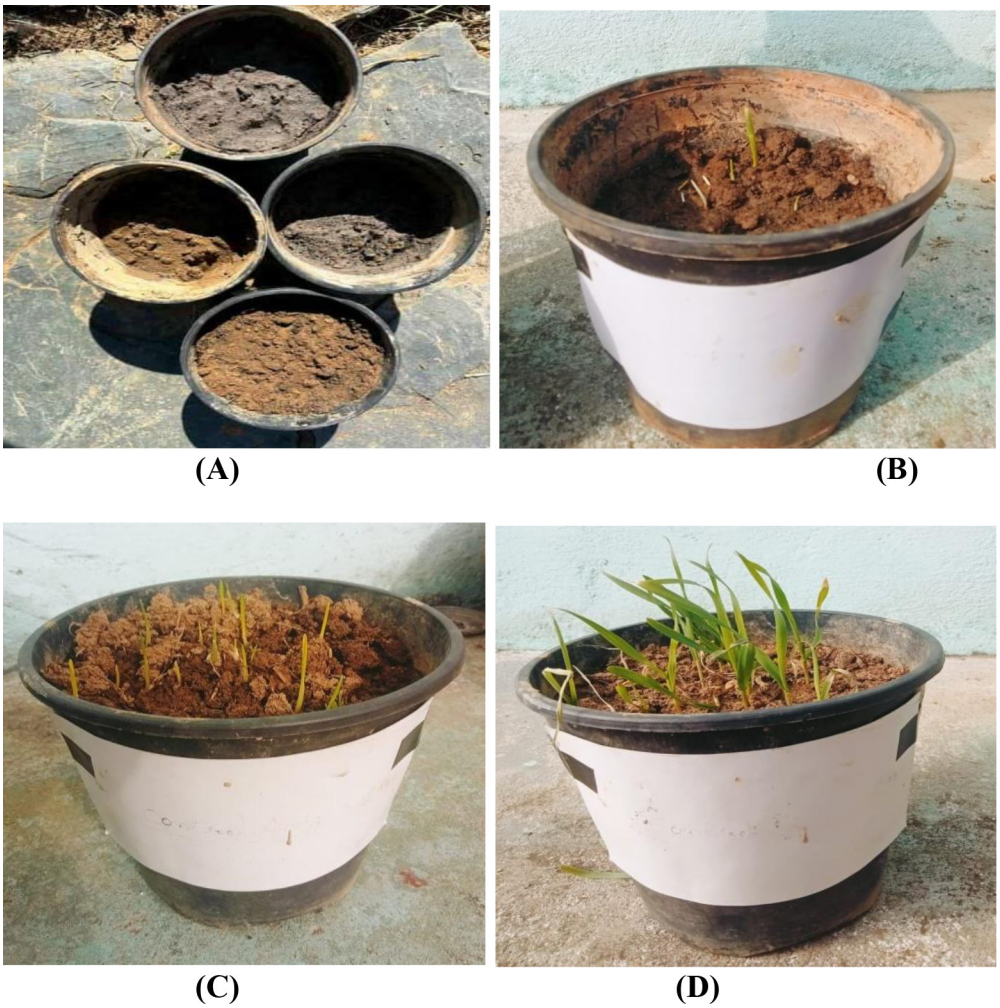


Figure 3. Effect of *Havan* ash on seed germination and plant growth. **(A).** Pot filled with soil mixed with *Havan* ash. **(B).** Germination and early growth of *Jaun* seedlings in a control (untreated) pot at 6 days after sowing. **(C).** Germination and early growth of *Jaun* seedlings in soil amended with *Havan* ash, observed 6 days after sowing. **(D).** Progression of germination and vegetative growth of *Jaun* seedlings in *Havan* ash–amended soil at 3 weeks after sowing.

4. Conclusion

Significant differences in physical condition, colour, pH, solubility, and elemental content were found in the physicochemical and mineral studies of ashes formed from plants, herbal *agarbatti* ash, and *Havan* ash. Like other plant ashes, *Havan* ash is alkaline by nature and has moderate amounts of important macro- and microelements like Na, Ca, K, Mg, P, Fe, Cu, Ni, and Zn. Its reported biological activity is mostly attributed to these mineral elements. Experiments on seed germination and growth using *Jaun* (*Hordeum vulgare*) revealed that, in comparison to the control and other plant ashes, *Havan* ash treatment significantly increased both the germination percentage and seedling growth. In comparison to the untreated control, seedlings in soil amended with *Havan* ash showed a 32% increase in shoot length and a 49% rise in root length after 6 days. *Havan* ash demonstrated a 21% greater germination rate than the untreated soil, indicating an improvement in germination success as well. Seedlings in soil modified with *Havan* ash showed consistent vegetative development over 3 weeks, confirming the soil's positive effects. *Havan* ash's balanced mineral availability and alkaline nature, which lowers soil acidity while adding vital nutrients necessary for seedling development, are responsible for the improved germination and early growth. *Havan* ash had better effects on mean seedling length and germination rate than deodar and pinus wood ashes.

All things considered, the results show that *Havan* ash has a great deal of agronomic potential as a soil supplement. Its mineral profile is balanced but mild, which improves growth performance, seed germination, and seedling vigour. These findings point to the potential use of *Havan* ash as a natural soil conditioner and biofertilizer in sustainable agriculture. To verify its effectiveness, optimise application dosages, and evaluate any possible ecological effects, more long-term and field-level research is advised.

5. Author Contribution

V. Rana, S. Kumar and N. Bithel contributed to the conceptualisation, experimental and study design, K. Gahtori and K.D. Jakhmola performed the data analysis, S.K. Jawla and M.D. Sharma was written and reviewed the manuscript, M.D. Sharma and A.B. Bajpai revised the manuscript. All authors have read and agreed to the published version of the manuscript.

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