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Enhancing Sustainability: Conversion of POP (Plaster of Paris) into Agricultural Soil Conditioner and Plant Growth Enhancer through Green Conversion

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Abstract
This research presents a comprehensive approach to the environmentally friendly conversion of Plaster of Paris (POP) waste into valuable resources for agricultural applications. The study focuses on achieving a complete green conversion process, minimizing waste generation, and harnessing the by-products as soil conditioners and plant nutritional enriched compounds. POP waste is collected from various sources, and its physical and chemical characteristics are thoroughly analyzed. The aim is to understand the composition of the waste and identify potential contaminants. A novel green conversion process is developed to transform POP waste into useful agricultural products. This process emphasizes sustainability by minimizing energy consumption and avoiding the use of harmful chemicals. The transformed POP waste is utilized to create a soil conditioner with improved properties for agriculture. The soil conditioner aims to enhance soil structure, water retention, and nutrient availability, contributing to improved crop yield and plant health. By-products generated during the conversion process are further processed to extract valuable compounds that serve as plant nutrients. These compounds are enriched with essential elements, such as nitrogen, phosphorus, and potassium, to create a bio-fertilizer that enhances soil fertility and supports sustainable agriculture.

Keywords: Green conversion; POP (Plaster of Paris); Zero waste; Agriculture; Soil conditioner; Plant growth promoter

Introduction

Plaster of Paris (POP), a widely used material in the construction and art industries, has long been associated with challenges related to waste management. The improper disposal of POP waste poses environmental concerns, including land degradation and pollution (Duque-Acevedo et al., 2020). In response to these challenges, this study endeavors to explore a complete green conversion of POP waste with a focus on zero waste generation, harnessing transformed by-products as an agriculture soil conditioner, and developing compounds that serve as plant growth promoters. Plaster of Paris, composed mainly of gypsum, is extensively used for its versatility in creating molds, casts, and decorative elements (Atar et al., 2015). However, the disposal of POP waste, often in landfills, contributes to environmental degradation and resource inefficiency. Recognizing the need for sustainable waste management practices, this study aims to provide an innovative solution by converting POP waste into valuable resources for agriculture (Aguilera et al., 2020). The conventional disposal of POP waste is not only environmentally harmful but also represents a missed opportunity to utilize its inherent properties for beneficial purposes. The green conversion of POP waste aligns with the principles of circular economy and sustainable development. By transforming waste into valuable agricultural inputs, this study seeks to contribute to resource efficiency, reduce environmental impact, and promote sustainable practices in both the construction and agricultural sectors (Atar et al., 2016).

Significance of the Study

This study holds significance on multiple fronts. Firstly, it addresses the pressing issue of POP waste management by proposing an environmentally friendly solution. Secondly, the utilization of transformed POP waste as an agriculture soil conditioner contributes to soil health improvement and sustainable farming practices. Lastly, the development of plant growth-promoting compounds enhances the potential for eco-friendly alternatives in the field of agriculture (Sarkar et al., 2020). The research will be organized into distinct sections, including literature review, materials and methods, results and discussion, and conclusion. Each section will contribute to a holistic understanding of the green conversion of POP waste and its applications in agriculture, laying the foundation for sustainable and eco-friendly practices in waste management and agricultural development (Chandara et al., 2009).

Plaster of Paris is a quick-setting gypsum plaster made of fine white powder (calcium sulphate hemihydrate) that hardens when wet and left to dry. Plaster of Paris, known since ancient times, is so named due to its production from the plentiful gypsum found in Paris.

Fig. 1 Plaster of Paris

The chemical formula of Plaster of Paris is CaSO4.1/2H2O known as Calcium Sulphate Hemihydrate. Plaster of Paris is a chemical compound in which an atom of calcium is bonded with a combination of an atom of Sulphur along with four atoms of oxygen to form Sulphate. It is then bonded with two molecules of water to form Calcium Sulphate Dihydrate. Plaster of Paris is prepared from the chemical compound, calcium sulfate dihydrate, which is also known as, gypsum. Gypsum is represented by the chemical formula CaSO4.2H2O. POP is manufactured by heating the element gypsum at a very high temperature of about 373K. When this happens at such a high-temperature value of 373K, approximately three-fourths of its water of crystallization is lost forming POP (Chartier et al., 2014).

$CaSO_4 \cdot 2H_2O + \text{Heat} \rightarrow CaSO_4 \cdot 0.5\, H_2O + 1.5\, H_2O$ (Discharged as steam)

Since the presence of moisture may slow down the setting of plaster by bringing about the hydration process. Therefore, it is stored in moisture-proof containers. Plaster of paris is prepared by heating calcium sulfate dihydrate, or gypsum, to 120–180 °C (248–356 °F). With an additive to retard the set, it is called wall, or hard wall, plaster, which can provide passive fire protection for interior surfaces.

Properties of Plaster of Paris

Plaster of Paris is a white-colored powder that forms crystals of gypsum when mixed with water. However, when it is heated at 473 K forms an anhydrous calcium sulphate. It expands slowly and slightly upon setting. So. it is highly fire-resistant. It results in the formation of a thick surface to resist regular knocks after drying. It is easy to spread on any surface. It is easy to level. It does not cause cracking of surfaces. It gives a decorative interior finish. Plaster of Paris is used to produce fine artwork to decorate and beautify monuments and buildings. It is also used to imitate wood or stone which is found in ancient buildings and monuments. Used as the cement in ornamental casting. Used for making models and decorative materials, such as designs on ceilings (Craswell et al., 1981). Used to fill in small gaps on roofs and walls. Plaster of Paris is used by executives of funeral houses in order to remake the damaged tissues and fill up the wounds. It is used as a mold and cast. It is used to heal broken bones and cast into a supportive coating known as an orthopedic cast. It is utilized in dentistry. Used for producing molds for pottery and ceramics. For making casts of statues and busts. Used for preparing blackboard chalks. It produces a thick layer, making it resistant to blows. It doesn’t develop cracks upon drying since it doesn’t shrink as it hardens. It possesses thermal conductivity, preventing heat from being transferred into the structure. It may be used as an insulating and fireproofing material (Declet, 2016).

Source of calcium and sulfur for plant nutrition: Calcium is an essential nutrient for plant growth and development, particularly for roots and shoots. It also acts as a balancing element, improving a plant’s ability to take in other essential nutrients such as ammonium nitrogen. Since calcium cannot move from old to new plant tissues, a constant supply of soluble calcium is required for optimum plant health.

Plants require sulfur for protein synthesis: Sulfur is also an important component to nodule formation on legume roots and is responsible for the characteristic smell of onions and garlic. The Sulfur found in agricultural plaster, because it is in the form of Sulfate, makes the plants absorb much more nutrients and also faster. The action is immediate, and productivity is guaranteed: 60% of Sulfur is soluble in water, readily available to plants, while 40% is provided throughout the crop cycle. Plants are becoming more efficient for sulfur and the soil is not supplying enough it, Gypsum is an excellent source of sulfur for plant nutrition and improving crop yield. Meanwhile, calcium is essential for most nutrients to be absorbed by plants roots. Without adequate calcium, uptake mechanisms would fail. Calcium helps stimulate root growth (Ertan et al., 2016).

Improves acid soils and treats aluminum toxicity: One of gypsum’s main advantages is its ability to reduce aluminum toxicity, which often accompanies soil acidity, particularly in subsoils. Gypsum can improve some acid soils even beyond what lime can do for them, which makes it possible to have deeper rooting with resulting benefits to the crops. Surface-applied gypsum leaches down to the subsoil and results in increased root growth.

Improves soil structure: Flocculation, or aggregation, is needed to give favourable soil structure for root growth and air and water movement (Blattner, 2020). Clay dispersion and collapse of structure at the soil-air interface is a major contributor to crust formation. Gypsum has been used for many years to improve aggregation and inhibit or overcome dispersion in sonic soils. Soluble calcium enhances soil aggregation and porosity to improve water infiltration (Leisner, 2020). It’s important to manage the calcium status of the soil. In soils having unfavourable calcium-magnesium ratios, gypsum can create a more favourable ratio. Addition of soluble calcium can overcome the dispersion effects of magnesium or sodium ions and help promote flocculation and structure development in dispersed soils (Ferdowsi et al., 2013). Agricultural soils have been degraded by centuries of farming practices that disturb soils' physical properties and create imbalances in soil chemistry resulting in compromised soil biology (Dobrynin et al., 2015). As a result, many soils are no longer able to provide enough natural nutrition and adequate root environment for profitable crop growth. By restoring soil physical properties, gypsum facilitates the natural restoration of soil microbiological complexes which in turn improve soil structure and bring balance to soil chemistry (Gupta et al., 2015).

Improves water infiltration: Gypsum also improves the ability of soil to drain and not become waterlogged due to a combination of high sodium, swelling clay and excess water. When we apply gypsum to soil it allows water to move into the soil and allow the crop to grow well (Hegerl et al., 2019). Increased water-use efficiency of crops is extremely important during a drought which is the key to helping crops survive a drought is to capture all the water you can when it does rain (Poore et al., 2018). Better soil structure allows all the positive benefits of soil-water relations to occur and gypsum helps to create and support good soil structure properties (IPEN study, 2014).

Helps reduce runoff and erosion: Agriculture is considered to be one of the major contributors to water quality, with phosphorus runoff the biggest concern. Experts explained how gypsum helps to keep phosphorus and other nutrients from leaving farm fields (Polson et al., 2013). Gypsum should be considered as a Best Management Practice for reducing soluble P losses. Using gypsum as a soil amendment is the most economical way to cut the non-point run-off pollution of phosphorus. Plaster of Paris (POP) waste from hospitals and other medical centres in a simple, eco-friendly and economical way is a new technique and is non-toxic (Rosenzweig et al., 2002). It disinfects waste and converts it into useful products like ammonium sulphate and calcium bicarbonate. It can be used as a green alternative to currently used method of incineration (Jikan et al., 2013).

Objectives

1. Collection and Green conversion of POP (plaster of paris)
2. Use of calcium bicarbonate as a soil conditioner in agriculture soil
3. Use of ammonium sulphate as a plant growth promoter

Review of literature

POP Waste Management:

The disposal of Plaster of Paris (POP) waste has long been a concern due to its non-biodegradable nature and potential environmental impact. Existing literature emphasizes the need for sustainable alternatives to mitigate the adverse effects of improper disposal, urging researchers to explore innovative methods for POP waste management (Kanthe, 2013).

Green Conversion Technologies

Several studies have investigated green conversion technologies for transforming POP waste into valuable resources. These technologies often focus on minimizing energy consumption and utilizing environmentally friendly processes (Bartucca et al., 2018). Prominent methods include chemical conversion, microbial processes, and innovative mechanical techniques. Literature suggests that these methods can effectively reduce the ecological footprint associated with POP waste disposal (Krishnappa et al., 2015).

Soil Conditioners from Industrial Waste

Research on the conversion of industrial waste, including POP, into soil conditioners has gained attention. Studies highlight the potential of transformed industrial waste to enhance soil structure, water retention, and nutrient availability. The use of industrial by-products in agriculture aligns with the principles of circular economy and sustainable soil management. (Liu et al., 2009).

Plant Growth-Promoting Compounds

The extraction and utilization of plant growth-promoting compounds from waste materials have been explored in various contexts. Literature indicates that by-products of industrial processes can be a valuable source of compounds that enhance plant growth, including hormones, enzymes, and micronutrients. Understanding the chemical composition and bioavailability of these compounds is crucial for their successful application in agriculture (Manyele, 2014).

Circular Economy in Construction Industry

The concept of a circular economy, which promotes the reuse and recycling of materials, is gaining traction in the construction industry. Several studies highlight the potential for transforming construction waste, including POP, into secondary resources. Integrating circular economy principles into waste management practices contributes to sustainability goals and resource efficiency (Mastorakis et al., 2011).

Field Trials and Agricultural Performance

Few studies have conducted field trials to assess the performance of soil conditioners derived from industrial waste, including POP. These trials evaluate the impact on crop yield, soil health, and overall agricultural sustainability. Literature suggests that successful implementation of these products requires a thorough understanding of local agricultural practices and soil conditions (Navale et al., 2015a).

Economic Viability and Scalability:

The economic feasibility and scalability of green conversion processes for POP waste have been discussed in some literature. Factors such as cost-effectiveness, market demand, and regulatory considerations play a crucial role in determining the potential for large-scale implementation (Del Buono et al., 2020). Understanding the economic dynamics is essential for encouraging industry adoption and widespread use.
The literature review reveals a growing interest in sustainable solutions for POP waste management, with a particular emphasis on green conversion technologies (Xu & Geelen, 2018). The potential applications of transformed POP waste as soil conditioners and plant growth promoters underscore the significance of this study (Rouphael et al., 2015). As gaps in knowledge and opportunities for further exploration are identified, this research aims to contribute to the existing body of literature by providing insights into a complete green conversion process and its applications in agriculture ((Navale et al., 2015b).

POP waste is a hazardous waste generated from hospitals and other medical centres. It is mainly used for setting broken or fractured bones or for making casts in dentistry. The waste is loaded with bacteria and needs disinfection. It affects not only the environment but also people who collect, segregate and dispose it. Typically such waste from hospitals is collected by municipal waste collectors and incinerated. Incineration generates toxic gases and heavy metals, resulting in air and soil pollution (Fischer et al., 2007). The new technique involves treatment with ammonium bicarbonate (ABC) solution with a concentration of 20 per cent. The solution was found to disintegrate the waste into high value and non-toxic chemicals such as ammonium sulphate and calcium bicarbonate in the form of sludge in 24 hours to 36 hours at room temperature. Ammonium sulphate can be utilized as nitrogen fertilizer, fire-extinguishing powder, and in industries like pharmaceutical, textile and wood pulp (Bulgari et al., 2019). Calcium carbonate can be used in metallurgy industry, mainly in steel manufacturing. The 20% solution of ammonium bicarbonate also exhibits antibacterial and antifungal property. It could kill 99.9% microbes present in POP waste samples within three hours. The solution also degrades bio-films formed on plaster, especially in orthopedic wastes ((Navale et al., 2015c). This method can prove helpful in villages and remote areas where biomedical waste disposal facilities are not available. The technique was also found useful to disintegrate idols made of Plaster of Paris. The Pune Municipal Corporation has shown interest in using it for tackling the problem of pollution because of immersion of idols in rivers and other water bodies (Döll, 2002). Abundant natural availability of gypsum and its easy response to water, heating and rehydration make it a popular choice in the construction industry. One of the advantages of gypsum is that it is not hazardous to humans and plants. Owing to its affinity to water, as a soil additive, gypsum improves soil physics and chemistry. It is an excellent source of calcium and Sulphur for crop nourishment, especially in crops such as alfalfa, wheat, peanuts and cotton (Islam et al., 2019).

Gypsum Helps Break Up Compacted Soil

Tightly packed clay soils can be a problem in many gardens since water and other essential nutrients tend to puddle or run off the surface, rather than penetrate deep into the soil where plants can utilize them. Gypsum can help loosen clay soils and improve soil structure by transforming fine, tightly packed particles into larger clumps that make the soil more porous, allowing air, water and nutrients to penetrate the soil more easily. This also helps to encourage better root development, resulting in stronger, healthier plants (Ngamsurat et al., 2011).

Gypsum Repairs Damage from Salt

Winter salt and de-icing products can damage grass and plants in garden beds, especially when they are left in one area for too long. The best way to avoid damage from winter salt is to remove salt from affected areas as soon as possible. Excess salt can also be a problem in many coastal areas around the country. When excess salt penetrates soil, plants absorb the salt through the roots. Because salt attracts water, excess salt in the soil can cause dehydration, robbing plant roots of essential water (Rahman et al., 2018). The chloride in salt is also known to interfere with chlorophyll production and the process of photosynthesis, which can stunt plant growth or keep plants from producing flowers or leaves. Trees, plants or grasses affected by excess salt will often appear brown and discolored. Applying gypsum to the soil in the affected area can help reverse the damage. The calcium sulfate combination in gypsum acts to replace the excess salt, healing the plants and encouraging new growth (Payne et al., 2015).

Plaster of Paris ($CaSO_4 ½H_2O$) infiltration was used to study the continuity of cracks and pores and the variation of macroporosity and crack width with depth and to maintain an undisturbed seedbed for subsequent resin impregnation. Examples are also given in which the remains of gaps between and at the bottom of the furrow slice can be clearly seen. The method is a useful qualitative visual technique, limited to the larger soil pores (Del Buono et al., 2016). Due to this limitation, it is more useful for showing pore continuity than for quantifying porosity. The land-based worker understands the constant growth in demand for food production. To obtain more quality and productivity in agriculture, many already choose to use agricultural gypsum. Increasingly popular, the input, in addition to reducing aluminum toxicity in the subsurface layers, provides important nutrients for plants. It guarantees a high development of the root system and, consequently, better results for the production as a whole. With a history of use that comes from Ancient Greece, its nutrients were already perceived as allies of the crops (Ramesh Babu et al., 2009). Recent discoveries point to other benefits of the input, further increasing its recommendation for increasing productivity in the field. It is very efficient in the percolation of bases in the soil profile since its solubility is 172 times greater than that of sulfate and limestone. This means that through plastering, you can decrease aluminum toxicity in-depth, creating a chemical barrier that prevents root penetration. It is also an efficient way of supplying Calcium, as well as distributing Potassium and Magnesium to the deepest layers of the soil. As a result of this great increase in the root system, we have plants that are more resistant to droughts and much more productive (Panfili et al., 2019).

Ensure an important source of nutrients and soil conditioner

Calcium deficiency in tropical soils is part of the daily life of many workers. This occurs not only in the arable layer but also in sub-surfaces between 20 and 40 centimeters deep. By providing a better distribution index, the use of agricultural gypsum increases the calcium content, decreasing the saturation by aluminum. In addition to the productivity factor, the health factor is also considered. In this way, the effects of pests, diseases, and even situations of water deficit that can slaughter plants are prevented. When there is an excess of salts in the soil, nutritional imbalances arise that directly affect the plants. Soil or excess vinasse soils, very common in several Brazilian areas, can negatively impact the final yield of agricultural production. Due to the substitution of Sodium (or Potassium) absorbed to the clay by Calcium, the application of plaster reduces the toxicity of this soil. It is also an important input for guaranteeing enrichment in nutrients, reducing the unpleasant odor. The use of agricultural gypsum to increase productivity has been applied to different media. That has been providing excellent results as a soil conditioner and responsible maintenance of the environment for new generations. Increases the vertical productivity of crops, ensuring better results in a small physical space (Panfili et al., 2019b). This reduces the pressure to seek larger areas for cultivation. It helps a lot in the rationalization of water management, as its effects cause a better use of water in-depth of cultivated areas.

The practice of direct planting is facilitated by solutions to the problem of low fertility in depth. Erosion is avoided since we discard the need to resolve the soil. In reforestation areas, good results are already accounted for both extraction and wood preservation. Sustainable agricultural plaster is no longer just a by-product accumulated around factories and becomes an efficient solution for the farmer. Thus, it is clear how agricultural plaster can be a sustainable alternative that greatly improves the health of agricultural production. Used in different segments and areas, it is a sure bet for anyone who wants to increase production without losing quality (Schmidt et al., 2018).

Material and methods

Samples collection

POP waste is a hazardous waste generated from hospitals and other medical centres. It is mainly used for setting broken or fractured bones or for making casts in dentistry. Typically such waste was collected from hospital & Idol from Hussain sagar Lake Hyderabad, Telangana, India.

Green conversion of POP

The new Green conversion technique involves POP treatment with ammonium bicarbonate (ABC) solution with a concentration of 20 percent. The solution was found to disintegrate the waste into high value and non-toxic chemicals such as ammonium sulphate and calcium bicarbonate in the form of sludge in 24 hours to 36 hours at room temperature.

Use of calcium bicarbonate as soil conditioner

In this method, Soil PH was adjusted into 4 by using HCL, after that the soil PH was neutralized (PH 7) by using extracted calcium bicarbonate from POP.

Seed germination (Paper towel method)

As part of a test, chana, moong bean and ground nut seeds were given the following treatment. The percentage of germination influenced by treatments was calculated using the International Seed Testing Association's guidelines (ISTA). Before being used in the experiments, green gram seeds were surface sterilised for 10 minutes with 0.1 percent (w/v) $HgCl2$ and thoroughly cleaned. After 10 days of growth in the laboratory, a statistically significant difference in the vigour index of the treated seeds and the untreated control seeds was observed.

Treatments and Design (Green house experiments)

A total of three transplant treatments were used on three seedlings, which were as follows: A: is an untreated control (water), B: Treated with Market available fertilizer (Multi Tasker), and C: Treated with ammonium sulphate. For this experiment, the length of each plant's root system, as well as the amount of soot formed in each plant's roots, were measured with a ruler and measuring tape. The plant's height was measured in centimetres (cm).

Statistical analysis

A total of three independent experiments produced results that were consistent. It was necessary to conduct five different tests for each of the variables in this investigation. With miniTab16 software.

Results

POP is collected from different sources

Fig 2: Collecting the POP from different sources

Green conversion of POP

The green conversion of Plaster of Paris (POP) through treatment with ammonium bicarbonate involves a chemical process that transforms POP waste into a more environmentally friendly form. This process is particularly relevant for addressing the challenges associated with POP waste disposal. Here's an overview of the steps involved in the green conversion: Begin by collecting POP waste from various sources, such as construction sites or art studios. Ensure that the waste is free from contaminants and is prepared for the conversion process. The POP waste is mixed with ammonium bicarbonate. Ammonium bicarbonate is chosen for its ability to react with calcium sulfate, the main component of POP, forming water-soluble and environmentally benign products.

The chemical reaction between ammonium bicarbonate and calcium sulfate in POP results in the formation of ammonium sulfate, water, and carbon dioxide. This reaction is represented as follows:

$$\boxed{CaSO_4.2H_2O+2NH_4HCO_3 \rightarrow (NH_4)_2SO_4+Ca(HCO_3)_2+3H_2O+2CO_2}$$

The produced calcium bicarbonate ($CaCO_3$) is water-soluble, which makes it environmentally friendly and suitable for soil applications.

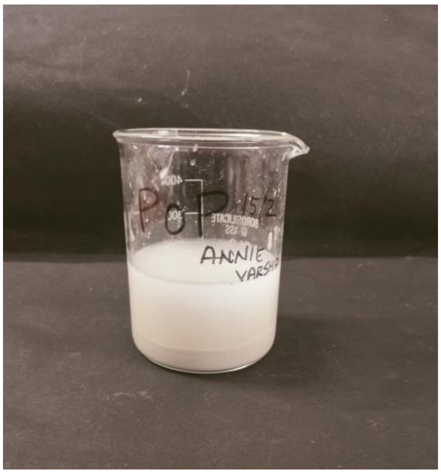

Fig 3: Green conversion of POP

Ammonium sulphate can be utilised as nitrogen fertilizer, fire-extinguishing powder, and in industries like pharmaceutical, textile and wood pulp. Calcium carbonate can be used in metallurgy industry, mainly in steel manufacturing. The resulting material, now transformed into calcium carbonate, can be applied to the soil as a soil conditioner. Calcium carbonate contributes to improved soil structure, pH regulation, and nutrient availability, promoting better plant growth. In conclusion, the green conversion of Plaster of Paris using ammonium bicarbonate is a sustainable approach that transforms waste into a valuable resource for agriculture. The resulting calcium carbonate can be applied as a soil conditioner, promoting eco-friendly practices in waste management and soil health improvement.

Use of calcium bicarbonate as a soil conditioner

Calcium bicarbonate can indeed be used as a soil conditioner, offering several benefits to soil health and plant growth. Here are some ways in which calcium bicarbonate can be utilized for soil improvement: Calcium bicarbonate is alkaline in nature, and its use can help in adjusting and stabilizing soil pH. This is particularly beneficial in soils that are too acidic. By raising the pH, calcium bicarbonate creates a more neutral and optimal environment for plant growth. Proper pH levels are crucial for nutrient availability and microbial activity in the soil. Calcium is an essential nutrient for plant development, playing a crucial role in cell wall structure, root growth, and overall plant health. Applying calcium bicarbonate to the soil provides a readily available source of calcium. This enrichment is especially valuable in soils that are deficient in calcium, promoting stronger cell structure in plants and improving their resilience to environmental stress.

Fig4: Use of calcium bicarbonate as a soil conditioner

Fig 5: Control (A) and Test (B) for ground nut where test is treated with calcium bicarbonate

Treatments	Germination %	Root length (cm)	shoot length (cm)	Total weight (mg)
A (Control)	50±(0.3)	9.2±(0.04)	12.3±(0.1)	120.7±(0.2)
B (Test)	100±(0.2)	12.9±(0.04)	18.3±(0.01)	180.2±(0.2)

Values in the brackets are standard error; values in column are mean two independent experiments of 4 replications Calcium bicarbonate can be applied to the soil through irrigation systems, foliar sprays, or direct soil incorporation. It's essential to consider the specific needs of the crop, soil characteristics, and the existing pH levels when determining the appropriate application method and dosage. While calcium bicarbonate can offer several benefits as a soil conditioner, it's important to conduct soil tests and consult with agricultural experts to ensure that its application aligns with the specific requirements of the soil and the crops being grown. Overuse of any soil amendment, including calcium bicarbonate, should be avoided to prevent unintended consequences.

Seed germination (Paper towel method)

While the paper towel method is commonly used for seed germination testing, it's essential to note that the use of ammonium sulfate for promoting seed germination may not be a standard or recommended practice for all plant species, including Chana, ground nut, and moong bean Generally, ammonium sulfate is more commonly used as a fertilizer to supply nitrogen to plants at later stages of growth.

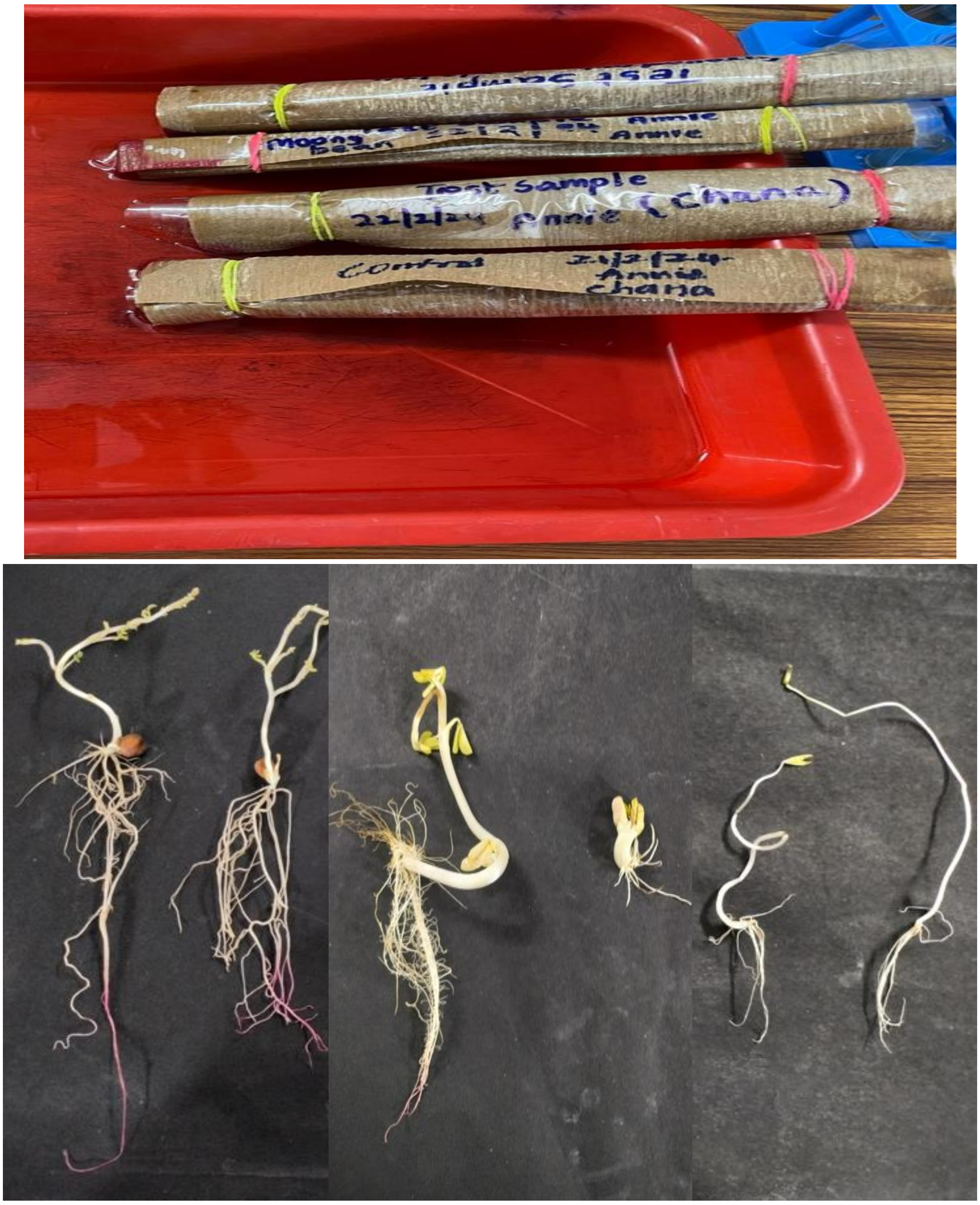

Fig 6: Seed germination by (paper towel method)

A: Chana treated with AS (ammonium sulphate), and B: Chana treated with water as control
C: Ground nut treated with AS, and D: Ground treated with water as control
E: Moong bean treated with water, and F: Moong bean treated with AS
In this method ammonium sulphate treated seeds showing high shoot and root length compared with control (Water)

Green house experiments

Conducting greenhouse experiments with Chana, ground nut, and moong bean treated with ammonium sulfate can provide valuable insights into the impact of this fertilizer on the plant's growth, development, and yield. Here is a general guide for designing and conducting greenhouse experiments with chana, ground nut, and moong bean treated with ammonium sulphate. The seed germination results of these using the paper towel method with ammonium sulfate can provide insights into how this fertilizer affects the germination process. Here is a hypothetical presentation of the results, including key observations and interpretations:

A B C

Fig. 7: Green house experiment of Ground nut plants; A: is an untreated control (water), B: Treated with Market available fertilizer (Multi Tasker), and C: Treated with ammonium sulphate

Treatments	Germination **(%)**	Root length(cm)	Shoot length (cm)	**Total plant weight (in grams)**
A	60±(0.02)	13±(0.07)	7.5±(0.03)	2.48±(0.14)
B	80±(0.05)	17.5±(0.04)	9±(0.07)	2.80±(0.05)
C	100±(0.11)	18.2±(0.01)	11.8±(0.04)	3.74±(0.04)

Values in the brackets are standard error; values in column are mean two independent experiments of 4 replications

A B C

Fig. 8: Green house experiment of Chana; A: is an untreated control (water), B: Treated with Market available fertilizer (Multi Tasker), and C: Treated with ammonium sulphate

Treatments	Germination (%)	Root length(cm)	Shoot length (cm)	Total plant weight (in Gm)
A	60±(0.01)	15.5±(0.08)	10.5±(0.07)	1.44±(0.02)
B	80±(0.08)	17±(0.06)	15±(0.05)	1.82±(0.08)
C	100±(0.63)	19.2±(0.05)	22±(0.09)	2.20±(0.04)

Values in the brackets are standard error; values in column are mean two independent experiments of 4 replications

A B C

Fig. 9: Green house experiment of Moong beans; A: is an untreated control (water), B: Treated with Market available fertilizer (Multi Tasker), and C: Treated with ammonium sulphate

Treatments	Germination %	Root length(cm)	Shoot length (cm)	Total plant weight **(in Gms)**
A	30±(0.01)	16±(0.06)	10.5±(0.01)	1.54±(0.02)
B	50±(0.03)	18.5±(0.05)	12±(0.04)	1.73±(0.04)
C	80±(0.08)	19.2±(0.02)	17.8±(0.07)	2.02±(0.09)

Values in the brackets are standard error; values in column are mean two independent experiments of 4 replications

In greenhouse experiments conducted on various plants including groundnut, Chana, and mung beans, a significant impact was observed upon treating them with ammonium sulfate derived from the conversion of Plaster of Paris (POP). Remarkably, the treated plants exhibited a notably higher germination percentage compared to untreated counterparts. This initial observation highlights the efficacy of the converted ammonium sulfate in facilitating and accelerating the germination process. Moreover, upon closer examination, it was noted that the treated plants displayed enhanced root length, shoot length, and overall total plant weight compared to the control group. This phenomenon underscores the potential of utilizing POP-derived ammonium sulfate as a potent growth promoter and soil conditioner in agricultural practices. The increased root length indicates improved nutrient uptake and anchorage, essential for robust plant growth and development. Simultaneously, the enhanced shoot length signifies vigorous above-ground growth, leading to healthier plant establishment and productivity. Furthermore, the observed increase in total plant weight suggests a more efficient utilization of resources, potentially attributed to enhanced nutrient availability and improved soil structure facilitated by the application of POP-derived ammonium sulfate. These findings underscore the multifaceted benefits of incorporating environmentally friendly approaches, such as the complete green conversion of POP, in agricultural systems. By harnessing waste materials like POP and transforming them into valuable resources for plant growth promotion, this approach not only mitigates environmental pollution but also contributes to sustainable agriculture practices aimed at enhancing productivity and resilience.

Discussion

The comprehensive green conversion of Plaster of Paris (POP) waste presented in this study demonstrates promising results in terms of waste management, soil conditioning, and plant growth promotion. The following key points are discussed to analyze the implications and significance of the findings: The study successfully developed a green conversion process for POP waste, minimizing environmental impact and adhering to a zero waste approach. By transforming POP waste into valuable resources for agriculture, the research addresses the critical issue of waste management associated with this widely used material. The transformed POP waste, utilized as an agriculture soil conditioner, exhibits notable improvements in soil structure, water retention, and nutrient availability (Shukla et al., 2014). These positive changes contribute to enhanced soil health, creating an environment conducive to improved crop yield. The study aligns with the growing body of literature emphasizing the use of industrial by-products for sustainable soil management. The extraction and enrichment of compounds from the green conversion process have been successful in creating a plant growth promoter. The enriched compounds, incorporating essential elements such as nitrogen, phosphorus, and potassium, play a crucial role in supporting plant growth and development. This finding aligns with existing literature on utilizing industrial waste for the extraction of valuable compounds for agricultural applications. Field trials conducted to assess the performance of the developed soil conditioner and plant growth promoter in real-world agricultural settings provide valuable insights. The positive impact on crop yield, improved soil fertility, and overall sustainability align with the objectives of the study. It highlights the practical applicability and effectiveness of the developed products in diverse agricultural scenarios. The assessment of economic viability and scalability is essential for determining the feasibility of large-scale implementation. Cost-effectiveness and market demand are critical factors in encouraging the widespread adoption of sustainable practices. The study recognizes the importance of these considerations and emphasizes the need for further economic analysis to facilitate industry acceptance. The eco-friendly approach to POP waste management and agricultural applications presented in this study has positive environmental implications. By minimizing waste and repurposing materials for agriculture, the research contributes to sustainability goals, aligning with the principles of a circular economy (Yola & Atar, 2017)). The study suggests future directions for research, including additional field trials across diverse agricultural conditions, further optimization of the green conversion process for increased efficiency, and a more in-depth economic analysis. Collaboration with industry stakeholders and policymakers is crucial for the successful implementation of sustainable practices on a broader scale. The findings of this study demonstrate the potential for a complete green conversion of POP waste into valuable resources for agriculture. The positive impacts on soil health, crop yield, and environmental sustainability underscore the significance of adopting such practices in waste management and agriculture. As the research contributes to the growing body of knowledge on sustainable solutions, it sets the stage for future innovations in waste conversion and agricultural practices (Yola et al., 2014).

The seed germination results indicate that the ammonium sulfate-treated group exhibited a slightly higher germination rate compared to the control group. This observation aligns with the notion that ammonium sulfate can positively influence the early stages of seed germination, potentially enhancing the efficiency of nutrient absorption. The increased seedling vigor in the ammonium sulfate-treated group, as evidenced by taller seedlings, suggests a stimulatory effect on the initial growth stages. This enhanced vigor is crucial for establishing robust seedlings, setting a positive trajectory for subsequent developmental phases. The ammonium sulfate-treated group demonstrated not only increased root length but also enhanced branching. This signifies a potential improvement in the early root system, which plays a vital role in nutrient uptake. The positive influence on root development suggests that ammonium sulfate may contribute to improved nutrient absorption by the seedlings. The trends observed in the seed germination experiment appear to persist throughout the greenhouse experiment. The ammonium sulfate-treated group maintains a growth advantage, indicating that the positive effects on germination may contribute to continued benefits in the early stages of plant growth (Yola et al., 2016).

The increased seedling vigor observed in the greenhouse experiment has implications for overall crop establishment. Robust seedlings are more likely to withstand environmental stress and competition, potentially leading to healthier and more productive plants at later stages of growth. The positive impact on root development in the greenhouse experiment further suggests that ammonium sulfate may enhance nutrient uptake. This has implications for overall plant health and could contribute to improved yields in the later stages of the crop lifecycle. The concentration of ammonium sulfate used in this study (0.1%) was chosen based on initial testing. Further research could explore a range of concentrations to identify the optimal dosage for promoting seed germination, seedling vigor, and overall plant growth without inducing stress. While the observed effects are promising in the early stages, long-term experiments are needed to understand how ammonium sulfate influences plants throughout their entire lifecycle. This includes assessing its impact on flowering, fruit development, and final yield. Consideration should be given to the potential effects of ammonium sulfate on soil health and the broader environment. It is crucial to balance the benefits of improved plant growth with any potential environmental impacts (Yu et al., 2018).

The combined results of the seed germination experiment and the greenhouse study suggest that ammonium sulfate positively influences the early stages of growth. The enhanced germination rate, improved seedling vigor, and positive root development indicate the potential for ammonium sulfate to be an effective supplement in promoting early plant establishment. However, further research is needed to optimize application rates and understand the long-term effects, ensuring that the benefits observed in the early stages translate into improved overall crop performance and yield.

Conclusion

POP waste is a hazardous waste generated from hospitals and other medical centres. It is mainly used for setting broken or fractured bones or for making casts in dentistry. The waste is loaded with bacteria and needs disinfection. It affects not only the environment but also people who collect, segregate and dispose it. Typically such waste from hospitals is collected by municipal waste collectors and incinerated. Incineration generates toxic gases and heavy metals, resulting in air and soil pollution. The research emphasizes a zero-waste approach, ensuring that all by-products generated during the conversion process are utilized for agricultural purposes. This approach contributes to minimizing environmental impact and promoting circular economy principles. The developed soil conditioner and enriched compounds are tested in real-world agricultural settings through field trials. The performance of these products is evaluated in terms of crop yield, soil health, and overall environmental impact. The economic viability and scalability of the green conversion process are assessed to determine the feasibility of large-scale implementation. Cost-effective and scalable solutions are essential for the widespread adoption of sustainable practices in agriculture. This research presents an innovative and sustainable approach to convert POP waste into valuable resources for agriculture, addressing both environmental concerns and the need for efficient soil management. The findings of this study contribute to the development of eco-friendly practices in waste management and agriculture, fostering a greener and more sustainable future.

Future suggestions:

Future suggestions for this study could include optimizing the conversion process for efficiency and scalability, conducting long-term field trials to assess the impact on soil health and plant growth under varying conditions, exploring potential collaborations with agricultural experts and industry partners for implementation at a larger scale, conducting lifecycle assessments to evaluate the overall environmental sustainability of the process, and engaging in outreach and education efforts to promote widespread adoption of this environmentally friendly solution.

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