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Full Length Research Article

Conversion of Soapstone Industry Waste into Value Added Fertilizer and its Effect on Soil Fertility and Growth of Tomato Plant

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Abstract

Soapstone is a magnesium-rich material that is frequently used to make carved sculptures and architectural features. Significant volumes of waste powder are produced during the processing of soapstone, most of which is currently land filled. Poor waste management has led to threats to human health and safety, a loss of aesthetic appeal, and land degradation. This waste contains specific micro and ultra micro plant nutrients but these nutrients are not easily accessible to plants when they are in waste powder form. In the current study, leftover soapstone powder was chemically transformed and its value-added fertilizer was prepared by combining vermicompost with converted soapstone waste. XRF study was performed on soapstone waste, soil, soil with vermicompost and soil with value added fertilizer and it was found that nutrient value increases for soil with value added fertilizer. To evaluate the efficiency of this value-added fertilizer on the growth and yield of tomato plants, three distinct types of experiments: control (simple soil), control + compost (soil + vermicompost), and varying percentages [Y, 2Y, 3Y, 4Y, and 5Y (Y = 3%)] of value-added soapstone fertilizer with soil were carried out. It was found that out of all the treatments 5Ydemonstrated the highest plant growth, crop yield, and biomass.

***Key words*:** Soapstone, Waste, Pollution, Fertilizer, Plant nutrients

Rajasthan is well recognized as museum of minerals due to its endless deposits of many kind of dimensional stones, including marble, dolomite, granite, lime stone, etc. Rajasthan has 57 percent of India's stone reserves. Rajasthan is one of the main producers of soapstone in India. Udaipur, Bhilwara, Pratapgarh, Dungarpur, Banswara, Rajsamand, Karauli, Alwar and Jaipur are the major soapstone producing districts in Rajasthan. Soapstone (steatite/soaprock) is a type of metamorphic rock and it is composed largely of the magnesium rich mineral talc. Soapstone is heat resistant, stain resistant, non-porous and resistant to attack from acids and bases [1]. Soapstone used in formation of sinks, cooking pots, cooking slabs, boiling stones, cemetery markers, electrical panels, ornamental carvings and sculptures, fireplace liners, woodstoves, wall and floor tiles, facing stones, bed warmers, marking pencils, moulds for metal casting etc.

The soapstone industry generates waste on large scale. About 30% to 40% of the material is wasted during mechanical processing (Fig 1). Slurry comprises up 20–30% of the finished products [2-6]. Quarry/cutting/sawing waste from in-situ stone sites and polishing trash from construction sites are the two forms of soap stone waste. The raw stone block is cut into tiles or slabs of various thicknesses using diamond blades during the stone processing process. While stone blocks are being cut into sheets of varied thickness, water is sprayed on the blades to cool them and absorb the dust (powder waste) produced during the cutting process. This activity generates a significant volume of effluent (slurry waste). It is not recycled since the water is so alkaline that reusing it will dull the polished slabs.

Fig 1 Powder waste produced in soapstone industry

This waste is now-a-days a serious problem which is threat to environment. As it is a non-biodegradable material,

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therefore poses numerous hazards. This waste can result in a range of respiratory issues, blurred vision, and environmental problems. If this stone waste is dumped on land, it has the potential to clog soil pores, damage the land's vegetation cover, and hasten the desertification of the area. It can reduce the rate of rain water percolating and deteriorate the soil fertility. Stone waste dumped in rivers, streams and seas contaminates them and responsible for the destruction of the aquatic ecosystem and water pollution. Therefore, it is necessary to investigate various options for reducing and managing this waste [7]. Minimization of this waste can be done by utilization of waste includes conversion of waste to useful, easily available, healthier and environmental friendly form.

Due to easily availability and abundant resources, many researchers performed their study on soapstone. Quintaes *et al*. [8] studied the soapstone cookware as a source of minerals. Huhta [9] studied the diversity of soapstone (classification and thermal behavior). Torres *et al*. [10] studied the technological properties of ceramic produced from steatite (soapstone) residues– kaolinite clay ceramic composites. Jamshidovna [11] studied the mineral chemical composition of the yakut saponite (soapstone) mineral and physical-chemical bases of complex trace elements. De-Souza *et al*. [12] studied the Gneiss and steatite vermicomposted with organic residues and release of nutrients and heavy metals. Cota *et al*. [13] investigated the incorporation of waste from ferromanganese alloy manufacture and soapstone powder in red ceramic production. Luukkonen *et al*. [14] worked on the mechanical properties, durability, and economic prospects of the alkali-activated soapstone waste. Chauhan *et al*. [15] reported an analysis on growth of soapstone mining in Rajasthan state. De-Souza *et al*. [16] investigated that vermicomposting with rock powder (Gneiss and steatite) increases plant growth.

Soapstone waste powder is a rich source of Mg, which is a secondary plant nutrient. Besides this, some other elements also found in this waste, which can be used for increasing soil fertility and plant growth. In the raw form, this waste is not in easily plant accessible form, hence direct application to the soil is not beneficial. It also blocks the pores of the soil resulting in degradation of soil productivity and this increases basicity of soil; hence this is not beneficial for those plants which require less pH for their development. Therefore, in the present research, to reduce harmful effect of soapstone industry waste, it is converted in easily plant accessible form, and its value-added fertilizer was prepared. Enrichment of soil was done by mixing soil with this value-added fertilizer. This value-added fertilizer is rich in Mg and tomato is Mg deficient plant, therefore effect of value-added fertilizer was performed on vegetative growth, crop yield and biomass of tomato plant.

MATERIALS AND METHODS

Soapstone waste: Waste powder of soap stone industry was collected from Kishangarh, Ajmer District of Rajasthan state. The chemical analysis of this waste is: SiO_2 = 61.08%, CaO = 1.40%, MgO = 30.00%, Fe_2O_3 = 1.00%, Al_2O_3 = 0.29%, LOI = 5.88%, Brightness = 97.30%, whiteness = 98.70%, Ret. on 500 Mesh = 0.19%.

Soil: Soil of Jaipur district of Rajasthan was collected for the study. The chemical analysis of soil is: organic matter = 4.47%, available Nitrogen as N = 223.2 kg/ha, available Phosphorous as P = 14.3 kg/ha, available Potassium as K = 228 kg/ha, Calcium as Ca = 8.32 mg/ kg, Magnesium as Mg = 3.65 mg/kg, alkalinity (as $CaCO_3$) = 20.2 mg/kg, Moisture = 1.8%, pH = 7.82, Electric conductivity = 0.810 dSm^{-1}, bulk density = 1.36 gm/cm^3.

Tomato seeds: Different types of treatments were performed on local variety of Tomato (*Lycopersicon esculentum) seeds* to find out their effect on plant development.

Soil preparation: For the experiment sufficient amount of soil was collected and mixed thoroughly on a clean plastic sheet and air dried for three days. It crushed with a wooden mortar and pestle and then sieved through a 2 mm mesh. This sieved soil was used for the experiment.

Chemical transformation of soapstone industry waste: Due to acid sensitivity of soapstone waste, concentrate Hydrochloric acid was used to dissolve it. Soluble salts (mainly chloride of Magnesium) and insoluble silicious residues were formed. The above solution along with insoluble treated with Diammonium hydrogen phosphate in the presence of ammonia solution. In alkaline medium phosphate hydrate (mainly $MgHPO_4$) precipitate and insoluble were obtained. The insoluble part is siliceous in nature and hence beneficial for plants so it does not require to remove. Soluble ammonium salts (D) were also formed which are acidic in nature and a major source of Nitrogen. Precipitated phosphate hydrates with insoluble were filtered, dried and used as converted waste (Fig 2).

$$MgO + 2HCl \longrightarrow MgCl_2 + H_2O + \text{Siliceous insolubles}$$

$$MgCl_2 + H_2O + \text{Silicious insolubles} \xrightarrow[NH_4OH]{(NH4)_2HPO_4} \underbrace{MgHPO_4 + \text{Insolubles}}_{\text{Converted soapstone waste}}$$

Fig 2 Converted product of soapstone industry waste

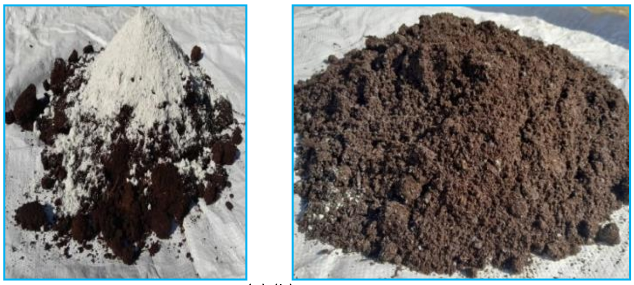
Formation of value-added soapstone fertilizer: To increase nutritious ability of this converted waste**,** it was mixed with vermicompost to prepare value added fertilizer (Fig 3).

Kitchen waste, plant leaves and cow dung were used to make vermicompost. After introducing earthworms (*Eisenia fetida* and *Eisenia andrei*), wet them time to time and covered them. Vermicompost is ready after around two months. When an earthworm consumes organic waste, the substrate travels through its gut and is digested by helpful bacteria in the worm's intestine. Vermicompost, a finely divided peat-like substance that is easily accessible to plants, is created in the intestinal tract as a result of the breakdown of substrate by enzymes, antibiotics, and mucus or chemical secretions.

$$\text{Converted soapstone waste + Vermicompost} \longrightarrow \text{Value added fertilizer}$$

XRF analysis: WD-XRF was used for the analysis of elements present in waste dolomite powder, soil, soil with vermicompost, and soil with value added soapstone fertilizer. Results of WD-XRF are included in (Table 2-3).

Experimental set up: The experiments were carried out by using pot culture technique as shown in (Table 1). C [Control (simple soil)], CC [Control + vermicompost (Soil containing recommended dose of vermicompost)], and VAS (value added fertilizer formed by mixing 10% converted soapstone waste powder with vermicompost, and then this was mixed with soil in equal amounts of recommended dose of vermicompost) were used to study the effect on development of tomato plant. To prevent mixing of the pots, the pots were given numbers before being filled with soil. In accordance with the plan of the study five doses of value-added compost - Y, 2Y, 3Y, 4Y, and 5Y (Y = 3%) were added to soil [VAS]. Nine replicates of each dose of the C, CC, and VAS were considered for experiment. Recommended dose of vermicompost and different % of value-added compost was mixed with the soil of the pots at the initial stage before sowing of seeds of tomato. Seed germination, plant height, No. of leaves, crop yield and biomass were studied to find out the effect of VAS on tomato plant development.



(a) (b)

Fig 3 (a) Mixing of converted soapstone waste with vermicompost and (b) formed value added fertilizer of soapstone industry waste

Table 1 Schematic presentation of pot culture technique of different types of the treatments

Treatments	C (Simple soil)	CC (Soil + vermicompost)	VAS (Soil + different % of value-added soapstone fertilizer)				
			Y	2Y	3Y	4Y	5Y
Pots	⌂	⌂	⌂	⌂	⌂	⌂	⌂

⌂ = Nine pots

RESULTS AND DISCUSSION

XRF analysis of Soapstone powder

XRF analysis result of waste soapstone powder is represented in (Table 2). This analysis reveals that this waste soapstone powder has an immense potential as a source of nutrients for the soil and plant. This waste contains primary plant nutrient (P, K), secondary plant nutrients (Ca, Mg, S), and micronutrients (Fe, Cl). Therefore, it can play an important role in enhancing soil productivity and plant growth.

Table 2 XRF analysis of Soapstone powder

Test parameter	Concentration (%)
Na	0.173
Mg	29.663
Al	0.194
Si	67.504
P	0.112
S	0.1
Cl	0.513
Ca	0.649
Fe	1.092

Enrichment of soil

The nutrient compositions of C, CC, and VAS are presented in (Table 3). It was clear that after conversion and value addition, the nutrient availability of waste soapstone powder was increased. It is clear that significant amount of macro and micro nutrients found in VAS. The primary nutrients of plants are N, P and K. Ca, Mg and S are secondary plant nutrients. Fe, Zn, Cu, Mn, B, Cl and Ni are micro nutrients and required less than 1000 ppm for plants. Na, Co, V, and Si are considered as beneficial plant nutrients. The concentration of P increases to 0.009% and 0.051% in VAS than C and CC respectively. The concentration of K in VAS is 0.002% more than C. The concentration of Ca in VAS increases to 0.468% and 0.003% than C and CC. VAS contain Mg is 3.125% and 3.035% more than C and CC. The availability of S is 0.295% and 0.007% more than C and CC.

Fe is 0.011% more in VAS than C and 0.245% less in VAS than CC. Mn is 0.013% and 0.028% more in VAS than C and CC. Ni is 0.915% and 0.759% less in VAS than C and CC respectively. In VAS Na is 0.915% and 0.759% less than C and CC. Si is 0.305% less and 0.609% more in VAS than C and CC respectively. Al is 0.932% and 1.054% less than C and CC in VAS. Sr is 0.006% and 0.009% more in C and CC than VAS. Cr is 0.013% more in VAS than C and 0.006% less than CC in VAS. Significant amount of oxides of Y, Zr, Ba, and Ti also present in VAS.

Table 3 XRF analysis of C, CC and VAS

Test parameters	Soil (C)	Soil + vermicompost (CC)	Soil + value added fertilizer of soapstone (VAS)
P_2O_5	0.559	0.517	0.568
K_2O	1.429	1.765	1.431
CaO	1.434	1.899	1.902
MgO	1.498	1.588	4.623
SO_3	-	0.288	0.295
Fe_2O_3	3.686	3.942	3.407
ZnO	0.015	-	-
MnO	0.078	0.063	0.091
NiO	0.287	0.017	0.014
Na_2O	4.051	3.895	3.136
SiO_2	73.21	72.296	72.905
Al_2O_3	12.677	12.799	11.745
Rb_2O	0.015	0.017	0.015
SrO	0.036	0.039	0.03
Cr_2O_3	0.101	0.12	0.114
Y_2O_3	0.006	0.004	0.005
ZrO_2	0.061	0.06	0.052
BaO	0.074	0.067	0.056
TiO_2	0.456	0.614	0.442

Effect of value-added fertilizer on tomato plant

Pot culture experiment was conducted to find out the effect of VAS along with C and CC on tomato plant by monitoring the following parameters at different time intervals.

Seed germination: (Fig 4) represented the tomato seed germination results of C, CC and different doses of VAS after 7, 10 and 15 days of sowing. After seven days of sowing in CC germination rate is equal to C, but it increases 10 and 15 days after sowing. CC is more nutritious in comparison to C and vermicompost present in CC has a solubilizing effect on several mineral compounds in the soil and causes the conversion of them into easily plant accessible forms, which is responsible for the quick germination process [17-18].

For VAS seed germination rate in Y and 2Y is equal to CC, but as it increases to 3Y to 5Y. The percentage of germination grows with increasing dosages of VAS as a result of a rise in the level of macronutrients to the level needed by the plant. Phosphorous (P), one of the plant nutrients, is essential for root development and seed germination. It supplies the necessary energy for the movement of nutrients. P encourages various plant functions, including respiration, energy storage and transfer, cell division, and cell development, all of which speed up seed germination. P is more abundant in VAS than C and CC. In VAS the highest germination was reported in 5Y. It might be explained by the easily accessible and readily available diverse mineral elements of plants in VAS. Early germination, root formation, and early growth in 5Y were primarily caused by high P content, which was supported by Mg, Ca and enhanced concentrations of other plant nutrients in 5Y VAS.

Ca is necessary for the development of cell membranes. Rapid cell division and development during root formation increases the need for calcium, hence the high Ca content in 5Y VAS also promote early germination.

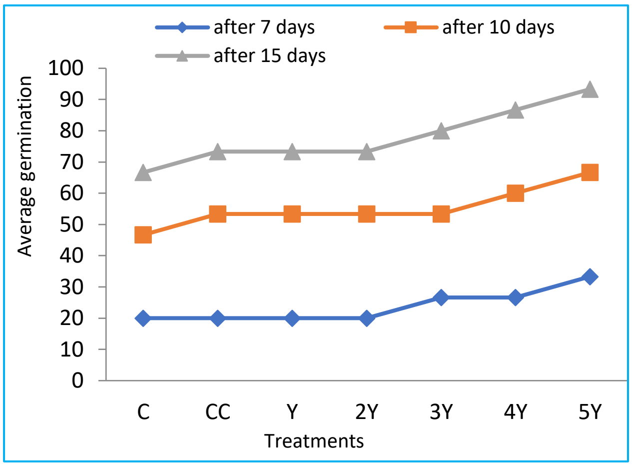


Fig 4 Average tomato seed germination % after 7, 10 and 15 days of sowing in different types of treatments

Plant height: Plant height data of C, CC and VAS are shown in (Fig 5). Among C and CC, tomato plant average height is more in CC. In CC, biological activity of earthworm responsible for soluble form of elements and transfer of nutrients to the plants. It is also responsible for electro conductivity of soil due to the exchangeable calcium, magnesium, and potassium found in worm cast. The key factors that contributed to the increase in electrical conductivity were the loss of organic matter and the release of different soluble ions in usable form (such as phosphate, ammonium, and potassium) from earthworm activity in vermicompost. This increases the number of microorganisms in the soil that encourage plant growth and directly stimulate plant growth by solubilizing nutrients [19-20].

In all the treatments plant height is maximum for VAS. In different concentrations of VAS, 5Y treated tomato plants having maximum plant height which may have resulted from the higher levels of macronutrients such calcium, magnesium, phosphorus, and potassium as well as a number of other micronutrients.

These nutrients encourage the production of some plant hormones that are necessary for plant's rapid growth. Ca is a component of cell walls and affects membrane permeability and structure. In addition to being an important part of chlorophyll and an enzyme activator, Magnesium (Mg) is also involved in protein synthesis, carbohydrate transport, and photosynthesis. S is a crucial part of plant proteins. P and K also play an important role as primary plant nutrient. Combined effect and increased level of all of these nutrients are responsible for maximum plant growth in 5Y VAS treatment.

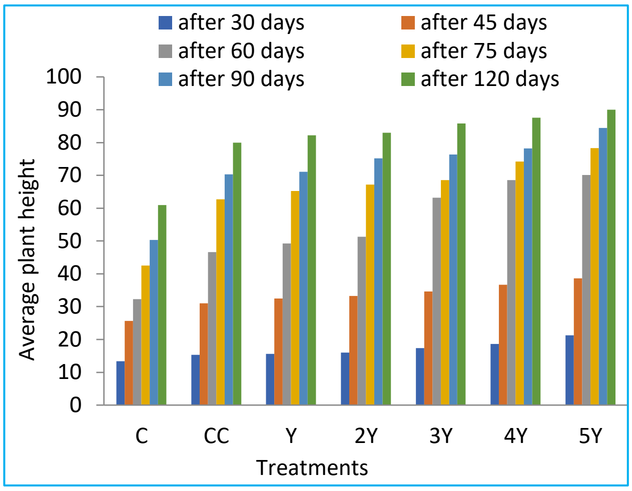


Fig 5 Average tomato plant height after 30, 45, 60, 75, 90 and 120 days in different types of treatments

Number of leaves: Average no. of leaves after 30, 45, 60, 75, 90 and 120 days in C, CC and different doses of VAS are shown in (Fig 6). In comparison to C, no. of leaves is more found in CC because CC is richer in plant nutrients than C. K is 0.336%, Ca is 0.465%, Mg is 0.09% and S is 0.288% greater in CC than C. In all the treatments maximum no. of leaves found in VAS. It is because VAS contains a lot of nutrients and makes them available forms that plants can absorb easily. In all treatments, 5Y VAS displayed the greatest number of leaves.

Mg is essential for leaf production and development. VAD contain Mg is 3.125% and 3.035% more than C and CC. Mg is also involved in a variety of biological processes, including the transfer of sucrose, energy metabolism, nitrogen usage, interactions between plants and soil microbes, and many others [21-26]. Additionally, it aids in the production of ATP and calcium pectinate, which functions as a cell wall adhesive. In chloroplasts, Mg is necessary for the synthesis of chlorophyll (Chl) pigments, which aid in the uptake of CO_2 during photosynthetic activities [27-29]. Only around 15–35% of the magnesium used by plants is fixed in Chl pigments, the balance (65–85%) is needed for protein synthesis and other important biological processes [30-31]. Magnesium is also used as a cofactor by more than 300 enzymes, including a number that are involved in Chl synthesis and photosynthetic CO_2 fixation [32-35]. Magnesium, a micro mineral found in VAS, activates a number of enzymes involved in the metabolism of proteins and carbohydrates. Mg and K play important roles in the creation of RNA and DNA, photosynthetic and respiratory responses, as well as the composition of chlorophyll and the activation of several enzymes [36-37]. Mg is required for the activation of a large number of other enzymes, such as protein kinases, RNA polymerases, glutathione synthase, adenosine triphosphatases (ATPases), phosphatases, and carboxylases [38-40].

The concentration of Ca in VAS increases to 0.468% and 0.003% than C and CC. A high Ca content in VAS is crucial for healthy leaf growth and development. Ca takes part in the metabolic procedures for absorbing other nutrients. By stabilizing cell wall structures, maintain the structural and functional integrity of the plant membrane, which strengthens plant tissues [41]. Ca is required for the growth of a fresh middle lamella. Since roots, stems, and leaves have continual cell division, this renders them particularly vulnerable to the low availability or absorption of calcium in soil. Since calcium is an immobile element in plants, it should be added to the soil when the plant is young. This is because the root system absorbs calcium quickly in the early stages of development, which helps to maintain the integrity of the membrane and stabilize the cell wall [42-43].

Significant amount of P, K, Fe, Mn and many other plant nutrients found in combination in VAS than C and CC. P encourages tissue growth and cell division. It is connected to the plant's intricate energy changes. Cytochromes, which are essential for plant transpiration, are formed from Fe. Chlorophyll is also produced with its aid. Mn regulates a number of oxidation-reduction processes as well as photosynthesis. The number of leaves rises because to the increased nutrient content in VAS. S is also helpful for the production of leaves. It is a crucial part of plant proteins. It is essential for the stabilization of N, the production of chlorophyll, and the activation of enzymes and vitamins. K controls stomatal activity to control water usage.

Therefore, it can be concluded that high nutrient availability in VAS responsible for highest no. of leaves in 5Y VAS.

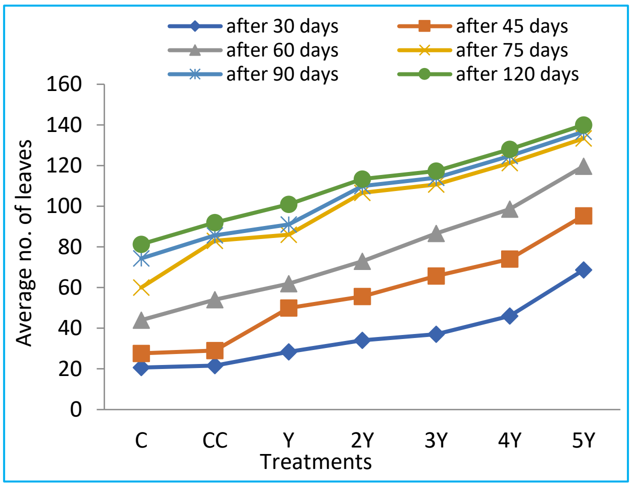


Fig 6 Average no. of leaves in tomato plant after 30, 45, 60, 75, 90 and 120 days in different types of treatments

Crop yield: Crop yield data for C, CC, and VAS are represented in (Table 4). Crop yield is the agricultural production that is harvested. It is directly related to the flowering and fruiting of the plant. (Fig 7) represents the average number of flowers per plant in C, CC, and different treatments of VAS. The average number of flowers that turn into fruit per plant in different treatments is reported in (Fig 8).

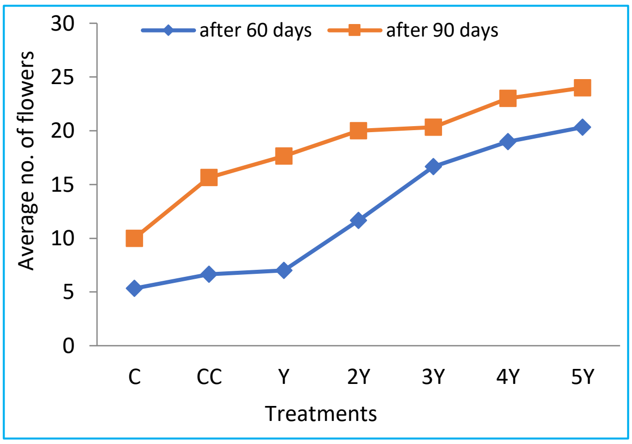


Fig 7 Average number of flowers after 60 and 90 days in different types of VAS treatments

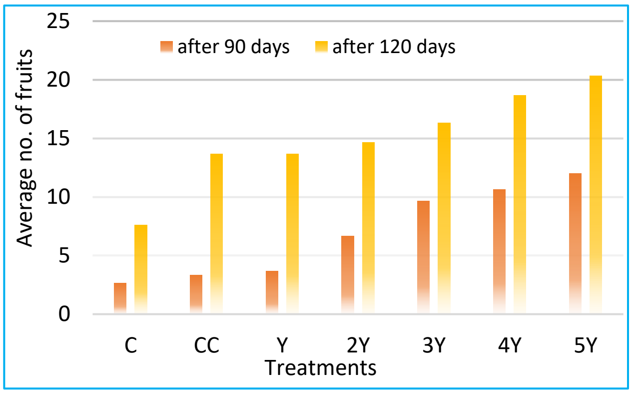


Fig 8 Average number of fruits after 90 and 120 days in different types of treatments

Table 4 Average crop yield of C, CC and different types of VAS treatments

Treatments	Average no. of fruits	Average fruit weight	Average crop yield
C	7.60	60.1	456.76
CC	13.66	62.22	849.92
Y	13.66	62.53	854.15
2Y	14.66	63.23	926.95
3Y	16.33	65.21	1064.87
4Y	18.66	67.58	1261.04
5Y	20.33	69.88	1420.66

Fruit weight measurements were also obtained in order to evaluate yield and compare it between various treatments and the control. Data shows that in the 5Y treatment, there were more flowers, and the majority of those flowers were turned into fruits in the same treatment. The addition of vermicompost with transformed mineral waste also greatly boosted the weight of the fruit. The crop yield was further increased by adding converted mineral waste to the vermicompost. It has an impact on fruit quality as well. The improvement in plant nutrition may provide an explanation for the rise in yield. By applying various doses of mineral-based fertilizer, the presence of macro- and micronutrients in the stone waste increased the nutritional status of value-added fertilizer, which may be the cause of the improvement in crop production.

Micronutrients and macronutrients both serve important roles in nutrition for increased quality and yield [44]. A crop's yield quality can be greatly improved by applying micronutrients and macronutrients in a balanced amount. Early transition of plant parts from the vegetative to reproductive phases, resulting in early flowering, may be caused by easy uptake of nutrients and simultaneous delivery of growth-promoting chemicals like cytokinins to axillary buds. These factors may also disrupt apical dominance. In addition to enhancing the physical condition of the soil, the use of both organic and mineral fertilizers increases crop output. To produce flowers and fruits, plants require a balanced source of nutrients, including N, P, K, Ca, Mg, and S. Highest % of Mg and Ca found in VAS. The pH of the soil and nutritional imbalances or deficiencies can have an impact on a plant's ability to flower and produce fruit. The enhancement of the physiochemical properties of the soil and the achievement of a balanced level of nutrients are the two factors that contribute to the stimulation of flowering in plants treated with value-added compost. The growth of fruits and flowers are also aided by micronutrients.

Florigen hormone is responsible for flowering in plants. It is produced in leaves and transmitted to the shoot apical meristem, where it starts the flowering process, via the phloem

[45]. The Ca ions bind to calmodulin in the florigen hormone's mechanism of action, and the Ca^{2+}/CaM signalling system then causes the expression of G1 mRNA or FT and CO mRNA. The plant flowers as a result of the daytime buildup of G1 mRNA, or GI-CO-FT mRNA [46]. As a result, 5Y VAS produces the more flowers because of its high Ca content, which favors early flowering compared to C and CC. Mg is necessary for stress tolerance, male fertility, and pollen generation. Both flowers and fruits require potassium to grow. Disease resistance is another benefit. It regulates how water is absorbed by the roots and released through the leaves. A high P level promotes earlier and more uniform crop maturity.

Growths of tomato plants at different time intervals are shown in (Fig 9-12).

Fig 9 Tomato plants growth after 30 days in (i) C, (ii) CC and (iii) VAS

Fig 10 Tomato plants growth after 45 days in (i) C, (ii) CC and (iii) VAS

Fig 11 Tomato plants growth after 60 days in (i) C, (ii) CC and (iii) VAS

Fig 12 Tomato plants growth after 75 days in (i) C, (ii) CC and (iii) VAS

Fig 13 Tomato plants growth after 90 days in (i) C, (ii) CC and (iii) VAS

Fig 14 Tomato plants growth after 120 days in (i) C, (ii) CC & (iii) VAS

Biomass

Data in (Fig 15) shows the average biomass data of tomato plant for C, CC and different types of VAS treatments. The weight of living plant material that is present above and below a specific unit of ground surface area at any given time is known as plant biomass. To calculate the biomass of tomato plants clipping and weighing method was applied. For this all the tomato plants were carefully removed from the soil system after full growth of the plant. The average difference between the fresh plant weight and the weight after drying 48 hours was used to compute the biomass.

It was found that there was a substantial difference between plants growing in untreated soil and those treated with vermicompost and value-added product. The increase in the quantity of macronutrients, micronutrients, and growth hormone necessary for the plant's optimum growth is responsible for the increase in biomass of the plants treated with vermicompost loaded with transformed mineral waste.

The variation in tomato growth, yield, and fruit quality may be a result of genetic differences, and transformed fertilizer, which can provide a variety of nutrients and enhance the physical and biological characteristics of the soil, can increase nutrient uptake, reduce nutrient losses, and improve fertilizer use efficiency, which increases the soil's availability of nutrients.

Fruit production and biomass were much higher in plants treated with value-added product. The crop's health and biomass are really attributed to several nutrient components found in the recycled stone refuse. This provides solid evidence that the soil's accessible minerals and organic extracts work together to significantly boost biomass. The plants take up these readily available nutrients from the soil, which stimulates vegetative growth and output.

The catalyst for increasing biomass is the presence of primary nutrients, secondary nutrients, essential nutrients, and ultra micro nutrients in the mineral waste. An increase in P has an impact on several different plant functions, including photosynthesis, respiration, energy storage and transfer, cell division, and cell enlargement. K is necessary for both the absorption of water and the production of plant sugar for consumption. K Promotes the growth of plants, (roots, fruits, seeds, etc.). Ca is essential for maintaining cell integrity and membrane stability.

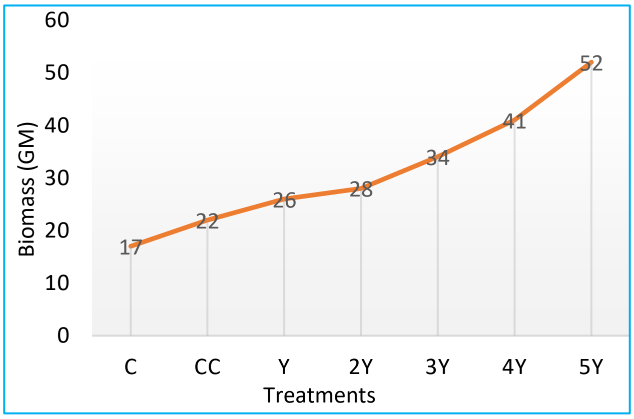


Fig 15 Biomass of C, CC and different types of VAS treatments

A number of enzymes involved in the metabolism of carbohydrates and the creation of the nucleic acids found in the chlorophyll molecule are activated by magnesium. A phosphatic carrier is Mg^{2+}. From cell wall growth to respiration, photosynthesis, chlorophyll creation enzyme activity, and nitrogen fixation and reduction, micronutrients actively participate in plant metabolism activities. Micronutrients like Mn, Fe, and others that are present in the value-added fertilizer enhanced both the quality and output of the crop. In comparison to C, CC, and other VAS treatments, biomass was increased in 5Y VAS due to all of these characteristics.

CONCLUSION

Waste from the soapstone industry is responsible for environmental contamination, water pollution, land degradation and infertility. XRF study revealed the presence of different types of plant nutrients in this waste. In the raw form the element present in this waste is in inert form and not easily accessible to plants. This waste is chemically transformed into value added fertilizer which is more easily plant accessible form and cost effective and doesn't create any type of environmental pollution. XRF study showed that this converted fertilizer is more nutritious than C and CC. Tomato plant is lack in Ca and Mg, and this value-added compost is rich in Ca and Mg. When applied to tomato plants, it was discovered that VAD performs better than C and CC in terms of seed germination, plant height, the number of leaves, crop production, and biomass. Due to the highest quantity of nutrients available in the 5Y treatment, all VAS treatments demonstrated the highest levels of vegetative growth, crop yield, and biomass. As a result, it can be concluded that recycling soapstone industry waste into value added fertilizer and utilizing it to boost crop production can be a very efficient strategy to stop environmental damage and find a solution to the problem of how to dispose of soapstone industrial waste. Additionally, it will support the economic expansion of these industries and offer a cost-effective method of meeting the crop's nutritional requirements.

Conflict of interest

The authors have no conflicts of interest to declare. This research received no external funding.

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LITERATURE CITED

1. Soltan AMM, Kahl WA, Hazem, MM, Wendschuh M, Fischer RX. 2011. Thermal microstructural changes of grain-supported limestones. *Mineralogy and Petrology* 103: 9-17.
2. Rana A, Kalla P, Verma HK, Mohnot JK. 2016. Recycling of dimensional stone waste in concrete: A review. *Journal of Cleaner Production* 135: 312-331.
3. Kaźmierczak U, Blachowski J, Górniak ZJ. Wirth H. 2018. Quantitative and qualitative research on the waste from the mining of rock raw materials in lower Silesia. *Minerals* 8: 375**.**
4. Kaźmierczak U, Blachowski J, Górniak ZJ. 2019. Multi-criteria analysis of potential applications of waste from rock minerals mining. *Applied Science* 9: 441.
5. Woźniak J, Pactwa K. 2018. Overview of polish mining wastes with circular economy model and its comparison with other wastes. *Sustainability* 10: 3994**.**
6. Fawad M, Ullah F, Shah W, Jawad M, Khan K, Wajid R. 2022. An integrated approach towards marble waste management: GIS, SFA, and recycling options. *Environmental Science and Pollution Research* 29(56): 1-11.
7. Yilmaz E. 2013. Advances in reducing large volumes of environmentally harmful mine waste rocks and tailings introduction. *Mineral Resource Management* 27(3): 89-112.
8. Quintaes KD, Amaya FJ, Morgano MA, Mantovani DMB. 2002. Soapstone (steatite) cookware as a source of minerals. *Food additives and contaminants* 19(2):134-143.
9. Hunta A. 2019. Diversity of soapstone: Classification and thermal behavior. *Ph. D. Thesis* 39.
10. Harlley SST, Angélica FDCV, Antônio CSS. 2015. Technological properties of ceramic produced from steatite (soapstone) residues–kaolinite clay ceramic composites. *Applied clay science* 112/113: 53-61.
11. Tursunova FJ. 2022. The study of the mineral chemical composition of the yakut saponite mineral and the physico-chemical bases of complex trace elements. *American Journal of Pedagogical and Educational Research* 7: 63-70.
12. De-Souza MEP, Cardoso IM, De Carvalho AMX, Lopes AP, Jucksch I. 2019. Gneiss and steatite vermicomposted with organic residues: release of nutrients and heavy metals. *International Journal of Recycling of Organic Waste in Agriculture* 8: 233-240.
13. Cota TG, Reis EL, Lima RMF, Cipriano RAS. 2018. Incorporation of waste from ferromanganese alloy manufacture and soapstone powder in red ceramic production. *Applied Clay Science* 161: 274-281.
14. Luukkonen T, Abdollahnejad Z, Yliniemi J, Mastali M, Paivo Kinnunen, Illikainen M. 2019. Alkali-activated soapstone waste - Mechanical properties, durability, and economic prospects. *Sustainable Materials and Technologies* 22: e00118.
15. Chauhan P, Meena M. 2018. An analysis on growth of soapstone mining in Rajasthan state. *International Journal of Creative Research Thoughts* 6(2): 1818-1821.
16. De Souza MEP. 2013. Vermicomposting with rock powder increases plant growth. *Applied Soil Ecology* 69: 56-60.
17. Gupta R, Yadav A, Garg VK. 2014. Influence of vermicompost application in potting media on growth and flowering of marigold crop. *International Journal of Recycling of Organic Waste in Agriculture* 3: 1-7.
18. Tomati U, Grappelli A, Galli E. 1988. The harmone like effect of earthworm casts on plant growth. *Biology and Fertility of Soils* 5: 288-294.
19. Karmegam N, Daniel T. 2009. Growth reproductive biology and life cycle of the vermicomposting earthworm, perionyxceylanensis mich (Oligochaeta:Megascolecidae). *Bioresource Technology* 100: 4790-4796.
20. Khwairakpam M, Bhargava R. 2009. Vermitechnology for sewage sludge recycling. *Journal of Hazardoud Materials* 161: 948-954.
21. Chen J, Li LG, Liu ZH, Yuan YJ, Guo LL, Mao DD. 2009. Magnesium transporter AtMGT9 is essential for pollen development in Arabidopsis, *Cell Research* 19: 887-898.
22. Ceylan Y, Kutman UB, Mengutay M, Cakman I. 2016. Magnesium application to growth medium and foliage affect the starch

distribution, increase the grain size and improve the seed germination in wheat. *Plant and Soil* 406: 145-156.
23. Ishfaq M, Zhong Y, Wang Y, Li X. 2021. Magnesium limitation leads to transcriptional down-tuning of auxin synthesis, transport, and signaling in the tomato root, *Frontiers of Plant Science* 12: 802399.
24. Li D, Ma W, Wei J, Mao Y, Peng Z, Zhang J. 2020. Magnesium promotes root growth and increases aluminum tolerance via modulation of nitric oxide production in Arabidopsis. *Plant and Soil* 457: 83-95.
25. Li LG, Sokolov LN, Yang YH, Li DP, Ting J, Pandy GKA. 2008. Mitochondrial magnesium transporter functions in Arabidopsis pollen development. *Molecular Plant-Microbe Interactions* 1: 675-685.
26. Xu XF, Wang B, Lou Y, Han WJ, Lu JY, Li DD. 2015. Magnesium Transporter 5 plays an important role in Mg transport for male gametophyte development in Arabidopsis, *Plant Journal* 84: 925-936.
27. Cakmak I, Kirkby EA. 2008. Role of magnesium in carbon partitioning and alleviating photooxidative damage. *Physiologia Plantarum* 133: 692-704.
28. Cakmak I,Yazici AM. 2010. Magnesium: a forgotten element in crop production. *Better Crops* 94: 23–25.
29. Gerendás J, Führs H. 2013. The significance of magnesium for crop quality. *Plant and Soil* 368: 101–128.
30. Karley AJ, White PJ. 2009. Moving cationic minerals to edible tissues: potassium, magnesium, calcium. *Current Opiion in Plant Biology* 12:291–298.
31. Marschner H. 2012. Marschner's mineral nutrition of higher plants, 3rd Ed. San Diego, CA: Academic Press, USA 89**.**
32. Billard V, Maillard A, Coquet L, Jouenne T, Cruz F, Garcia MJM. 2016. Mg deficiency affects leaf Mg remobilization and the proteome in Brassica napus. *Plant Physiology and Biochemistry* 107: 337–343.
33. Chen ZC, Peng WT, Li J, Liao H. 2018. Functional dissection and transport mechanism of magnesium in plants semin. *Cell and Developmental Biology* 74:142–152.
34. Ma CL, Qi YP, Liang W, Yang LT, Lu YB, Guo P. 2016. Micro RNA regulatory mechanisms on Citrus sinensis leaves to magnesium-deficiency. *Frontiers of Plant Science* 7: 201.
35. Peng HY, Qi YP, Lee J, Yang LT, Guo P, Jiang HX. 2015. Proteomic analysis of Citrus sinensis roots and leaves in response to long-term magnesium-deficiency. *BMC Genomics* 16: 253.
36. Doberman A, Fairhust A. 2000. Rice Nutrient Disorders & Nutrient Management. *International Rice Research Institute (IRRI) Zinc Deficiency And Potash & Phosphate Institute/Potash & Phosphate Institute of Canada* 29: 84-87.
37. Khwairakpam M, Bhargava R. 2009. Vermitechnology for sewage sludge recycling. *Journal of hazardous Materials* 161: 948-954.
38. Maguire ME, Cowan JA. 2002. Magnesium chemistry and biochemistry. *Biometals* 15: 203–210.
39. Shaul O. 2002. Magnesium transport and function in plants: the tip of the iceberg. *Biometals,* 15: 307–321.
40. Dann L, Wakeman CE, Sieling CA, Baker CL, Irnov SC, Winkler WC. 2007. Structure and mechanism of a metal-sensing regulatory RNA. *Cell* 130: 878-892.
41. Saeed B, Gul H, Khan AZ, Parveen L. 2012. Rates and methods of Nitrogen and Sulphur application influence and cost benefit analysis of wheat. *Journal of Agricultural, Biological and Environmental Statistics* 7(2): 81-85.
42. Demello R, Prado W, Natale JA, Silva A. 2005. Liming and quality of guava fruit cultivated in Brazil. *Scientia Horticulturae* 106: 91-102.
43. Hanson EJ, Bramlage WJ, Cline RA, Kushad MM. 1991. Calcium accumulation in delicious apple fruit. *Journal of Plant Nutrition* 14:1213-122.
44. Saeed B, Gul H, Khan AZ, Parveen L. 2012. Rates and methods of Nitrogen and Sulphur application influence and cost benefit analysis of wheat. *Journal of Agricultural and Biological Sciences* 7(2): 81-85.
45. Tsuji H. 2017. Molecular function of florigen. *Breeding science* 67(4): 337-332.
46. Gagliano M, Renton M, Depczynski M, Mancuso S. 2014. Experience teaches plants to learn faster and forget slower in environments where it matters. *Oecologia* 175(1): 63-72.