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A COMPARATIVE ANALYSIS OF DOLOMITE POWDER AND ITS CHEMICALLY CONVERTED VALUE-ADDED FERTILIZER ON SOIL PRODUCTIVITY AND GROWTH OF OKRA PLANT

D. Parmar[1], M. Choudhary[1], M. Jat[1], B. Pal[2] and Meenakshi[1,✉]
[1]Department of Chemistry, University of Rajasthan, Jaipur-302004, (Rajasthan),India
[2]Government Polytechnic College, Karauli-322241, (Rajasthan), India
✉Corresponding author: meenakshialwaraj@gmail.com

ABSTRACT

The mechanical processing of dolomite in various industrial applications generates a substantial amount of fine powder. This Dolomite powder is a rich source of calcium and magnesium, and it also contains trace amounts of essential micro and ultra-micro plant nutrients. However, in its raw form, these nutrients exhibit limited bioavailability for plant uptake. To enhance its agricultural utility, chemically transformed dolomite powder was integrated with vermicompost to develop a value-added fertilizer. In the present study, the transformed dolomite-based fertilizer was evaluated for its effects on the growth and yield of the okra plant under different treatment conditions. The experimental design included three primary setups: (i) control (unamended soil), (ii) soil with vermicompost (control + compost), and (iii) soil supplemented with varying concentrations of the value-added fertilizer [A, 2A, 3A, 4A, and 5A, where A = 3%]. Additionally, the impact of untreated dolomite powder was also assessed across different concentrations [a, 2a, 3a, 4a, and 5a, where a = 3%]. Results indicated that the value-added fertilizer significantly outperformed raw dolomite powder in promoting vegetative growth, enhancing biomass, and improving overall crop yield. Among all concentrations of dolomite, 3a performed best, while for its value-added fertilizer, 5A was excellent. The XRF results supported the enhancement in the nutritional value of the soil by mixing simple dolomite powder and value-added fertilizer. These findings suggested that the chemical transformation of dolomite powder into an easily plant accessible form, when combined with vermicompost, presents a promising approach for sustainable soil enrichment and improved plant productivity.

Keywords: Dolomite, Fertilizers, Plant Nutrients, Vermicompost, Okra, Crop Yield, Biomass.
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INTRODUCTION

India is one of the leading producers of raw and dimensional stones worldwide.[1] The Rajasthan state contains 57% of India's stone reserves, including marble, granite, dolomite, soapstone, and others. The principal districts in Rajasthan that produce dolomite are Ajmer, Bhilwara, Chittorgarh, Jaipur, Jaisalmer, Jodhpur, Udaipur, Rajsamand, and Alwar. Dolomite is a cost-effective and abundant natural mineral that is characterized by its versatility, non-toxicity, and simple handling.[2] Dolomite is the anhydrous carbonate mineral of calcium and magnesium.[3-5] Dolomite is frequently used in the steel industry because of its strength and efficiency in the purification process. Although dolomite has several uses, it is most commonly used in the construction sector as a limestone alternative.[6] Due to its high MgO content, dolomite is an essential raw material for the iron and refractory industries.[7,8] At present, the agricultural sector is facing acute challenges in meeting the increasing food production globally, particularly under the strain of climate change and soil degradation[9]. Fertilizers are necessary to supply nutrients to plants (crops), as nutrition is one of the most important factors for maintaining agricultural yield in terms of both quality and quantity. [10] The long-term excessive and inefficient use of fertilizers has caused a serious agricultural non-point source pollution issue.[11] To enhance soil sustainability and improve crop quality, some techniques like integrated nutrient management, recommended dose of fertilizer (RDF) are also applied these days.[12] In the present scenario, the prime focus is to fulfil agricultural food demand by achieving Sustainable Development Goals (SDG-2).[13] In the mechanical processing of dolomite (mining, quarrying, cutting, and shaping), a large quantity of dolomite powder was also produced.[14] This dolomite

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powder is a very good source of Ca and Mg. In spite of its readily availability and cost-effectiveness, dolomite powder is still not used on a large scale as a proper fertilizer. Yet some researches have been performed on the use of dolomite powder as fertilizer on different types of plants.[15-24] Dolomite powder also contains some additional elements that can be utilized to boost plant development and soil fertility. But dolomite powder is not readily plant-accessible in its raw state, so it is not advantageous to apply it directly to the soil. Because of its extremely small particle size, it clogs soil pores, decreasing soil productivity and increasing soil basicity.[25-27] As a result, dolomite powder is beneficial for plants that require basic soil for growth, but not good for plants that need a lower pH to grow.[28, 29] Yet this dolomite powder is used on a vast scale in steel, glass, ceramic, etc. industries, but in the agriculture sector, its consumption is not in large amounts. It plays only a small role in increasing the basicity of the soil. Therefore, the purpose of the study is to remove the drawbacks related to its application as fertilizer and make it more suitable for all types of soils and all types of crops. According to the United Nations's 17 sustainable development goals (SDGs), SDG2 is related to zero hunger, which can be achieved by minimum input and maximum output in the agricultural sector. To follow up on SDG 2, in this study, dolomite powder was converted into a readily plant-accessible form, and its value-added fertilizer was prepared. Okra (*Abelmoschus esculentus*) is one of the world's oldest cultivated crops, which belongs to the Malvaceae family. It is the local crop of Rajasthan and easily grows in the climatic conditions of Jaipur, Rajasthan. Therefore, a comparative analysis of raw dolomite powder and its value-added fertilizer, along with simple soil and vermicompost, was performed on okra plants to find out the efficiency and workability in terms of vegetative growth, crop yield, and biomass.

EXPERIMENTAL

Soil

For this study, Soil was collected from the Narayan Vihar area of Jaipur, Rajasthan, India. The chemical analysis of soil is presented in Table-1.

Table-1: Chemical Analysis of Soil

Parameters	Concentration
Alkalinity	20.2 mg/kg
Mg	3.65 mg/kg
Ca	8.32 mg/kg
Bulk density	1.36gm/cm^3
Available K	228 Kg/ha
Available P	14.3 Kg/ha
Available N	223.2 Kg/ha
Organic matter	4.47%
Electrical conductivity	0.810 dSm^{-1}
pH	7.82
Moisture	1.8%

Dolomite Powder

In the present research, dolomite powder was collected from Rajgarh, Alwar, Rajasthan, India. The chemical analysis of dolomite powder is shown in Table-2.

Table-2: Chemical Analysis of Dolomite Powder

Parameter	% in dolomite
MgO	11.80%
CaO	36.68%
SiO_2	8.45%
Al_2O_3	0.13%
Fe_2O_3	0.73%
$CaCO_3$	65.50%

$MgCO_3$	24.78%
Brightness	89.20%
LOI	41.80%
Ret. on 300 mesh	1.52%
Whiteness	92.60%

Okra Seeds

Local variety of Lady finger (*Abelmoschus esculentus)* seeds were used in the study.

Soil Preparation

A total of one and a half quintal of soil was collected and subjected to air drying for 72 hours under ambient conditions. The dried soil was subsequently pulverized using a wooden mortar and pestle to achieve a uniform particle size. It was then sieved through a 2 mm mesh to remove coarse fragments and obtain a homogeneous soil matrix for further analysis.

Chemical Conversion of Dolomite Powder

Dolomite is highly reactive to acidic conditions; thus, it was dissolved in concentrated hydrochloric acid. This process resulted in the formation of an insoluble siliceous residue and a solution containing soluble salts, primarily calcium and magnesium chlorides. The resultant solution was subsequently treated with diammonium hydrogen phosphate under alkaline conditions, leading to the precipitation of phosphate hydrates, primarily $CaHPO_4$ and $MgHPO_4$, along with additional insoluble residues. Given that the insoluble fraction is predominantly siliceous in nature and beneficial for plant growth, its removal was deemed unnecessary. Additionally, soluble ammonium salts, serving as a significant nitrogen source, were generated as a byproduct. The precipitated phosphate hydrates, including the insoluble fraction, were filtered, dried, and utilized as the converted product for further applications (Fig.-1 and 2).

Fig.-1: Chemically Converted Dolomite Powder

Formation of Value-Added Fertilizer from Dolomite Powder

The transformed dolomite-based product was integrated with vermicompost to formulate a value-added fertilizer, enhancing its overall nutrient profile (Fig.-3). Vermicompost was prepared using organic waste materials, including kitchen scraps and plant leaves, which were shredded and subsequently combined with cow manure. The prepared mixture was inoculated with red wiggler earthworms (*Eisenia fetida* and *Eisenia andrei*), maintained under controlled moisture conditions, and covered to facilitate microbial activity and decomposition.

The vermicomposting process was completed in approximately two months. During this period, beneficial bacteria (microbiota) in the gut of earthworms assisted in the digestion of organic matter. As earthworms consumed and processed the organic waste, enzymatic activity, antibiotic production, and mucus secretions facilitated the breakdown of complex substrates into a finely divided, peat-like material. This biologically enriched vermicompost enhances nutrient availability and improves soil structure, making essential nutrients more accessible to plants.

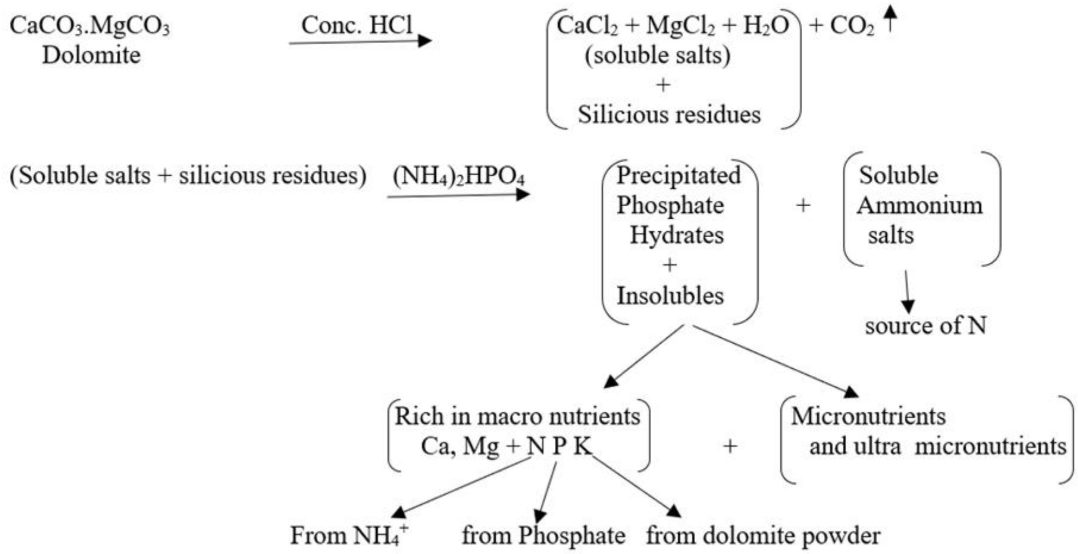

Fig.-2: Schematic Presentation of Chemical Conversion of Dolomite Powder

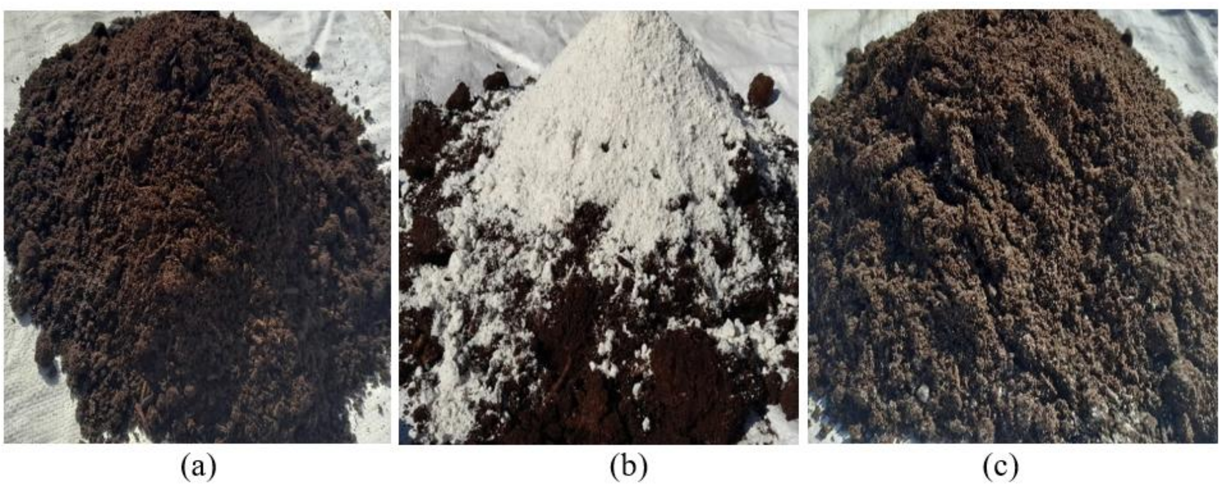

Fig.-3: Formed Vermicompost (a), Mixing of Converted Waste with Vermicompost (b), and Prepared Value-Added Fertilizer (c)

XRF Analysis

The analysis of elements in dolomite powder, soil, soil with vermicompost, soil with simple dolomite (SD), and value-added dolomite fertilizer with soil was carried out by X-Ray Fluorescence spectroscopic technique (XRF). Results of WD XRF are included in Table-4 and 5.

Experimental Setup

The study was conducted using a pot culture technique, as outlined in Table-3. The experimental design included four treatment groups: one with simple soil (control, C), a second was soil with vermicompost (CC), a third having soil with simple dolomite powder (SD), and the last with soil containing value-added fertilizer (VAD). VAD was formulated by incorporating 10% chemically converted dolomite powder with vermicompost, which was then mixed with soil at a recommended dose. The objective was to evaluate the effects of these treatments on the growth and development of okra. Key growth parameters, including seed germination rate, plant height, number of leaves, crop yield, and total biomass, were systematically assessed. To ensure accurate treatment application and prevent cross-contamination, all pots were prenumbered before filling with soil. The study included five graded doses of VAD-A, 2A, 3A, 4A, and 5A (where A = 3%) and five corresponding doses of simple dolomite powder- a, 2a, 3a, 4a, and 5a (a = 3%) mixed into the soil. Each treatment was replicated nine times to ensure statistical reliability. The recommended dose of vermicompost, along with varying concentrations of VAD, was incorporated into the soil at the initial stage before sowing okra seeds.

Table-3: Schematic Presentation of Pot Culture Technique

Treatments	C	CC	VAD					SD				
			A	2A	3A	4A	5A	a	2a	3a	4a	5a
Pots												

= Nine pots, A = 3%, a = 3%

Different Growth Parameters of the Okra Plant

Seed Germination: Before planting, okra seeds were soaked in water for 24 hours to enhance germination potential. A pot culture experiment was conducted to assess the variation in germination percentage across different treatment groups, including C, CC, varying doses of SD, and VAD. Germination rates were recorded after 7 and 10 days of sowing. The findings are shown in Fig.-4.

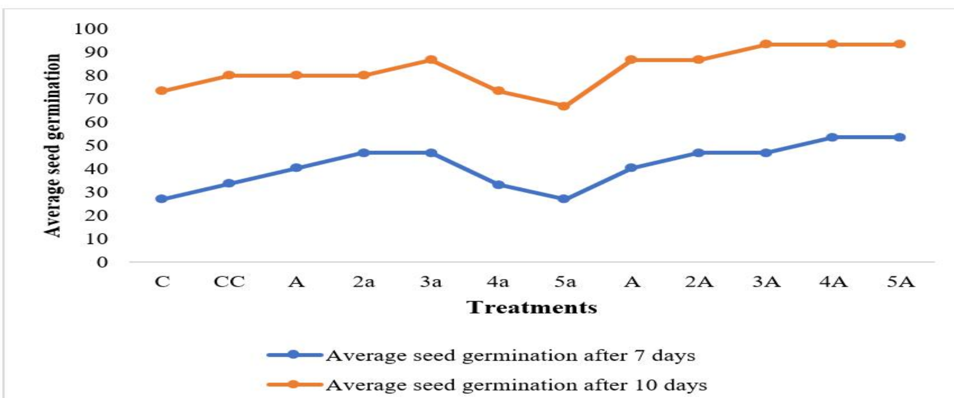

Fig.-4: Average Seed Germination Results of Okra Plant

Plant Height

Plant height, measured as the vertical distance from the base of the stem at the soil surface to the apex of the plant, was recorded for C, CC, SD, and VAD treatments and shown in Fig.-5.

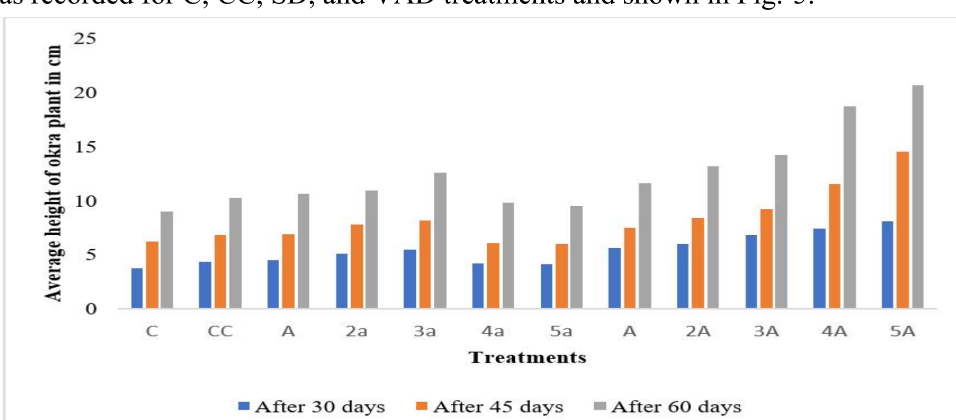

Fig.-5: Average Height Results of Okra Plant

Number of Leaves

The average number of leaves per plant was recorded at 30, 45, and 60 days after sowing for treatments with varying doses of value-added fertilizer (VAD) and simple dolomite (SD), alongside control (C) and control with compost (CC) treatments. Figure-6 shows the number of leaves for different types of treatments.

Crop Yield

It is related to the productivity of the plant. Average no. of fruits and average crop yield are represented in Fig.-7 and Table-6, respectively.

Biomass

The sum of the net average plant weight and crop output is known as biomass. To calculate biomass, a clipping and weighing approach was employed. In order to record the biomass, okra plants were carefully taken from the soil system after they had reached full size, taking care not to damage any parts of the plant. The weight difference between the freshly clipped plant and after 48-hour weights was used to compute biomass. The plants were dried after being softly cleaned with a trickle of water. Following that, the weight of the recently clipped plants was determined. Following a 48-hour air drying period, they are weighed. Figure 8 shows the biomass data of okra plants under various treatments.

RESULTS AND DISCUSSION

XRF Results

The effect of dolomite powder on soil fertility was analysed by the X-ray fluorescence technique**.** The XRF analysis of dolomite powder is presented in Table-4. XRF analysis results of soil, soil with vermicompost, soil with dolomite powder (SD), and soil with value-added fertilizer are presented in Table-5.

Table 4: XRF Analysis of Dolomite Powder

Elements	Concentration (%)
Sr	0.05
Fe	1.443
Mn	0.156
Ca	72.214
K	0.273
Cl	0.115
S	0.04
P	0.104
Si	7.115
Al	1.278
Mg	16.531
Na	0.681

Table- 5: XRF analysis of C, CC, SD, and VAD

Test Parameter	Simple soil (C)	Soil+ Vermicompost (CC)	Soil + Dolomite Powder (SD)	Soil + Value-added Fertilizer (VAD)
BaO	0.074	0.067	0.059	0.068
ZrO_2	0.061	0.06	0.054	0.048
SrO	0.036	0.039	0.036	0.036
Rb_2O	0.015	0.017	0.017	0.015
ZnO	0.015	-	0.018	-
NiO	0.287	0.017	0.017	-
Fe_2O_3	3.686	3.942	3.704	3.658
MnO	0.078	0.063	0.073	0.086
Cr_2O_3	0.101	0.12	0.075	0.181
TiO_2	0.456	0.614	0.464	0.553

CaO	1.434	1.899	3.719	2.399
K_2O	1.429	1.765	1.643	1.564
SO_3	0.323	0.299	0.46	0.241
P_2O_5	0.559	0.517	0.593	0.604
SiO_2	73.21	72.296	70.79	71.735
Al_2O_3	12.677	12.799	12.717	12.877
MgO	1.498	1.588	2.397	2.392
Na_2O	4.051	3.895	3.567	3.54
Y_2O_3	0.006	0.004		0.004
Nb_2O_5	0.003	-	-	-

Effect on Okra Plant

The effect of C, CC, and various SD and VAD dosages on okra plant growth has been investigated by monitoring the different parameters across different periods of time. Results of seed germination, plant height, number of leaves, number of fruits, and biomass are shown in Fig.- 4 to 8, respectively, and crop yield results were represented in Table-6. Growth of the okra plant after 30, 45, and 60 days is shown in Fig.-9 to 11, respectively. Biomass-related pictures are shown in Fig.-12.

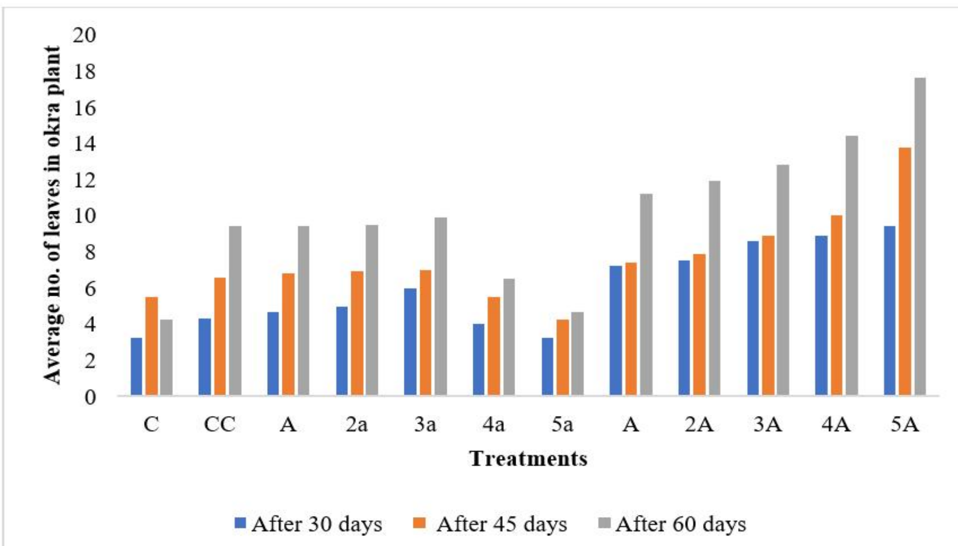

Fig.-6: Average no. of Leaves of Okra Plant

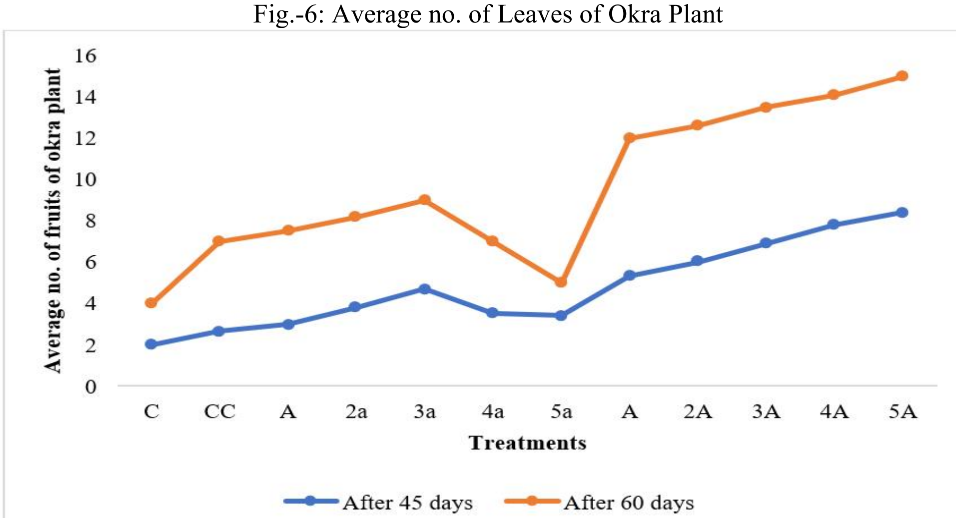

Fig.-7: Average no. of Fruits of Okra Plant

XRF Analysis of Dolomite Powder

The elemental composition of dolomite powder, as determined by X-ray fluorescence (XRF) analysis, is presented in Table-2.

Table-6: Average Crop Yield Results of Okra Plant

Treatments	Average no. of fruit	Fruit weight (gm)	Crop yield
C	4	14.2	56.8
CC	7	15	105
A	7.5	15.7	117.75
2a	8.2	16.4	134.48
3a	9	16.9	152.1
4a	7	15	105
5a	5	14.5	72.5
A	12	17	204
2A	12.6	17.3	217.98
3A	13.5	17.6	237.6
4A	14.1	18	253.8
5A	15	18.7	280.5

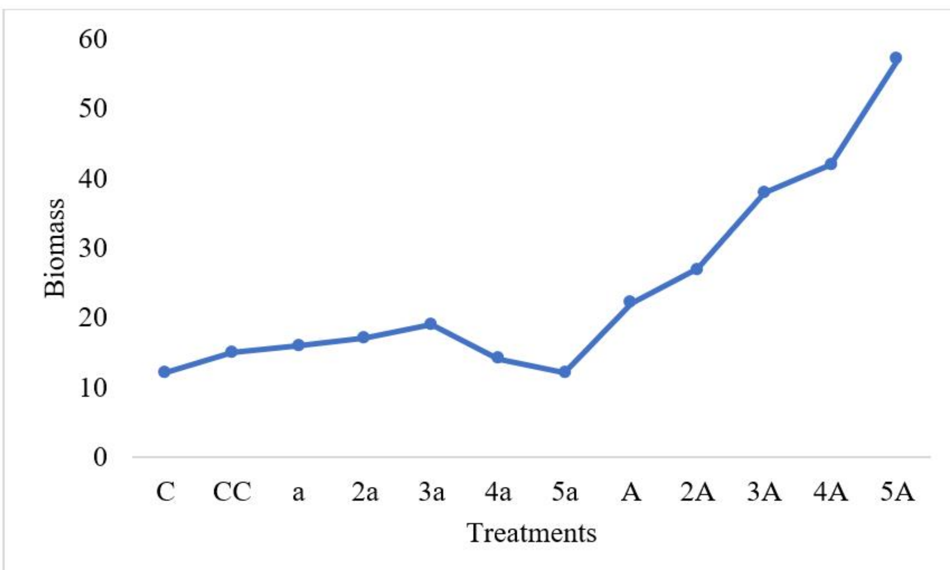

Fig.-8: Biomass of C, CC, and Different Treatments of SD and VAD

Fig.-9: Plant Growth after 30 days in C, CC (a), SD (b), and VAD (c)

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(a)


(b)

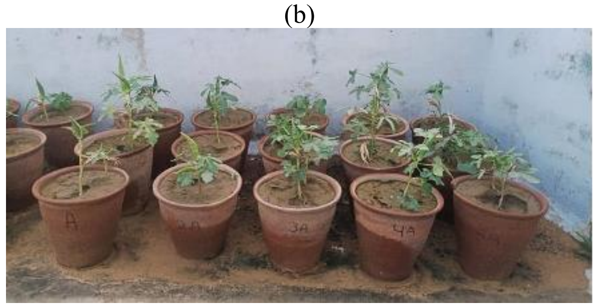

(c)

Fig.-10: Plant Growth after 45 days in C, CC (a), SD (b), and VAD (c)

(a)

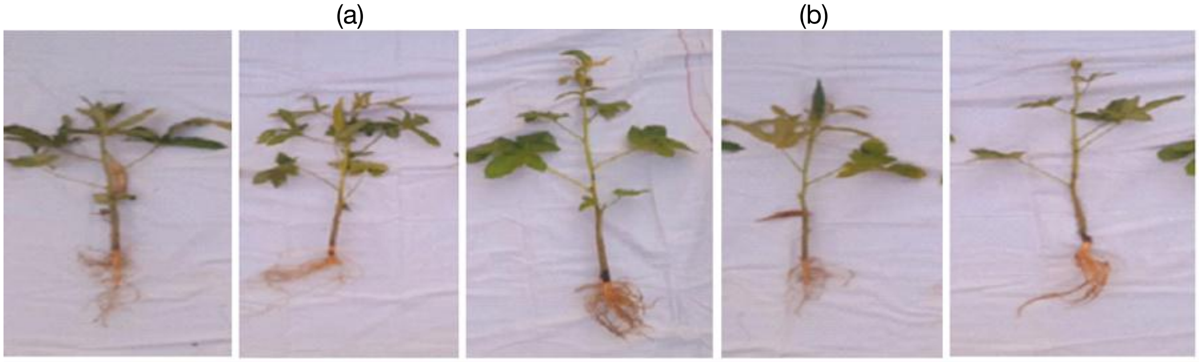

(b)

(c)

Fig.-11: Plant Growth after 60 days in C, CC (a), SD (b), and VAD ©

(a)

(b)



(c)

(d)

Fig.-12: Biomass Picture of C (a), CC (b), SD (c, from a to 5a), and VAD (d, from A to 5A)

The results indicate that dolomite powder has significant potential as a soil amendment and a plant nutrient source. The analysis revealed the presence of primary macronutrients, including phosphorus (P) and potassium (K), as well as beneficial elements such as sodium (Na) and silicon (Si). Additionally, dolomite powder was found to contain essential micronutrients, including iron (Fe), manganese (Mn), and chlorine (Cl), along with trace ultra micronutrients such as aluminum (Al) and strontium (Sr). Furthermore, secondary macronutrients such as calcium (Ca), magnesium (Mg), and sulfur (S) were present in substantial quantities. Given this diverse nutrient profile, dolomite powder has the potential to enhance soil fertility, improve plant growth, and support sustainable agricultural practices by supplying essential nutrients required for plant development.

XRF Analysis of C, CC, SD, and VAD

The primary nutrients of plants are N, P and K. Ca, Mg, and S are secondary plant nutrients. The concentration % of P increases to 0.087%, 0.045 % and 0.011% in VAD than in CC, C, and SD, respectively. The concentration of K is 0.135% greater than C in VAD. The concentration of Ca in VAD increases to 0.965% and 0.5% than CC and C. VAD contains Mg is 0.894% and 0.804% more than C and CC. The availability of S is 0.058%, 0.082%, and 0.219% lower than CC, C, and SD. Fe, Zn, Cu, Mn, B, Cl, and Ni are micro nutrients and required less than 1000 ppm for plants. Fe is 0.284%, 0.028% and 0.046% greater in CC, C, and SD than in VAD. Mn is 0.013, 0.023% and 0.008% greater in VAD than SD, CC, and C. Na, Co, V, and Si are considered as beneficial plant nutrients. In VAD, Na is 0.511%, 0.355% and 0.027% less than C, CC, and SD. Si is 71.735% in VAD, which is 0.561% and 1.475% lower than CC and C, respectively. In VAD, Si is 0.945% more than SD. Mo, Se, Al, Rb, Sr, Ni, Cr, and As are considered as ultra-micro nutrients for plants. Al is 0.16%, 0.078% and 0.2% more in VAD than SD, CC, and C, respectively. In VAD, Cr is 0.106%, 0.080% and 0.061% greater than SD, C, and CC. Significant amounts of Rb, Sr, and Ni are also present in VAD.

Effect on Okra Plant

To evaluate the effects of C, CC, varying doses of SD and VAD on the growth of okra, some physiological and agronomic parameters, i.e., average seed germination rate, plant height, number of leaves, crop yield, and total biomass were monitored at predetermined time intervals. The experimental setup allowed for systematic analysis of the influence of nutrient amendments on soil fertility and crop performance over time.

Seed Germination

The findings in Fig.-4 indicated that seeds in the CC treatment exhibited earlier germination compared to C, suggesting that the addition of compost facilitated improved seedling emergence and initial growth. The recorded results provide insights into the impact of soil amendments on seed germination dynamics. Extensive research has demonstrated that vermicompost is a rich source of plant growth regulators, including auxins, gibberellins, microbial cytokinins, and humic acids. These bioactive compounds play a crucial role in enhancing seed germination, root development, and overall plant growth. Additionally, vermicompost exhibits the ability to solubilize certain mineral compounds present in the soil, facilitating the conversion of various chemical constituents into accessible forms for plant uptake. This enhanced nutrient availability accelerates the germination process and promotes early seedling establishment, ultimately contributing to improved plant vigor and productivity. In the simple dolomite treatment, the highest germination percentages were observed in 2a and 3a, with 3a exhibiting the overall highest germination rate across all experimental treatments. This trend can be attributed to the enhanced essential plant nutrients present in SD. The early germination, root initiation, and initial seedling growth in 3a were primarily driven by its high phosphorus (P) content, which was further reinforced by the presence of calcium (Ca), magnesium (Mg), and other essential plant nutrients. Calcium plays a crucial role in cell membrane development and stability, contributing to efficient nutrient uptake and signal transduction. The elevated calcium concentration in 3a of SD likely facilitated rapid cell division and elongation during root formation, thereby accelerating the germination process. The lowest germination percentages were observed in the 4a and 5a treatments of simple dolomite (SD). This decline in germination can be attributed to the high concentration of dolomite powder, which likely created unfavorable soil conditions for okra seed germination, potentially due to excessive alkalinity or nutrient imbalances. Experimental data indicate that the application of VAD significantly enhances seed germination rates. As VAD dosage increases, the percentage of germinated seeds also rises, suggesting that the availability of macronutrients reaches optimal levels required for plant development. This indicated that VAD promotes seed germination in an environmentally friendly way according to SDG 2. Conversely, early germination was recorded at higher VAD concentrations (4A and 5A). This can be attributed to the improved bioavailability of essential mineral components in VAD, which facilitated optimal nutrient uptake. In particular, the elevated levels of calcium (Ca), magnesium (Mg), and other essential plant nutrients in 5A VAD contributed to enhanced root development and early seedling growth. The high phosphorus (P) content in 5A VAD played a crucial role in promoting rapid germination, as phosphorus is essential for energy transfer, root elongation, and overall metabolic activity during early plant development. Furthermore, calcium plays a critical role in cell membrane formation and stability, which is particularly important during root initiation. Since rapid cell division and elongation occur at this stage, an increased calcium demand is met by the high Ca content in 5A VAD, further supporting early germination and seedling establishment. Comparative analysis of nutrient composition reveals that VAD contains a higher concentration of phosphorus than SD, C, and CC, further supporting its superior effectiveness in promoting early plant growth.

Plant Height

Figure-5 showed the plant height data for C, CC, SD, and VAD treatments. The results indicate that vermicompost application significantly enhanced plant growth compared to the control, with the most pronounced effect observed in soil amended with value-added fertilizer. It is clearly visible that among all the treatments, eco-friendly VAD treatments are the most effective for height (growth) development of the plant according to SDG 2. The increased plant height in VAD-treated soil can be attributed to the synergistic effect of vermicompost-enriched converted dolomite powder, which enhanced soil nutrient availability. Earthworm activity in the vermicompost facilitated the transformation of organic matter into nutrient-rich castings, improving nutrient bioavailability for plant uptake. Notably, worm castings contain exchangeable calcium (Ca), magnesium (Mg), and potassium (K), which contribute to an increase in soil electrical conductivity. The rise in electrical conductivity was primarily due to the decomposition of organic matter and the subsequent release of soluble ions, including potassium (K^+), ammonium (NH_4^+), and phosphate (PO_4^{3-}), in bioavailable forms. Additionally, the presence of earthworm-associated microbial activity promoted nutrient solubilization, further enhancing plant growth. This microbial enrichment directly stimulated plant development by increasing root nutrient uptake efficiency and improving overall soil fertility. The highest plant height was observed in the 5A VAD treatment, which can be attributed to the increased concentrations of both micronutrients and macronutrients, including calcium (Ca), magnesium (Mg), potassium (K), phosphorus (P), and sulfur (S). These essential nutrients play critical roles in plant physiological processes, influencing growth and development through their involvement in hormone synthesis, metabolic pathways, and cellular functions. Calcium (Ca) is a structural component of the cell wall and regulates membrane permeability and integrity, thereby supporting cell expansion and division. Potassium (K) is essential for photosynthesis, carbohydrate translocation, and protein synthesis, all of which contribute to overall plant vigor and biomass accumulation. Magnesium (Mg) serves as an enzyme activator and is a fundamental constituent of chlorophyll, facilitating photosynthetic efficiency. Sulfur (S) is a key component of plant proteins and enzymatic processes, further supporting metabolic activity and growth. A rapid increase in plant height was observed during the first 60 days, likely due to the immediate bioavailability of these nutrients in the soil. However, after this period, no significant height increase was recorded, suggesting that nutrient uptake had reached saturation levels and that the plants had already absorbed the majority of the available nutrients necessary for further vertical growth. The presence of exchangeable potassium (K), magnesium (Mg), and calcium (Ca) in SD contributes to an increase in soil electrical conductivity, enhancing nutrient availability for plant uptake. Among the SD treatments, the highest plant height was observed in 3a, likely due to the elevated concentrations of both micronutrients and macronutrients, including Ca, Mg, P, and K. These essential elements play a crucial role in plant metabolism, promoting the biosynthesis of phytohormones that drive rapid plant growth and development. Low concentrations of dolomite powder in soil (a, 2a, and 3a) were found to have a positive effect on plant growth by increasing the concentration of beneficial plant nutrients and enhancing overall soil productivity. However, at higher concentrations (4a and 5a), excessive dolomite application induced an increase in soil alkalinity, creating suboptimal conditions for the growth of okra. Additionally, the fine particle size (300 mesh) of the dolomite powder used in this experiment facilitated its incorporation into soil pores. While this property is beneficial at lower concentrations, excessive dolomite application (4a and 5a) led to pore clogging, restricting water infiltration and reducing soil moisture availability. This impeded root hydration, further exacerbating plant stress. The combination of increased soil basicity and reduced water retention resulted in a decline in okra plant growth at higher dolomite concentrations.

Numbers of Leaves

Figure-6 represents the average number of leaves per plant for C, CC, SD, and VAD. A significant increase in leaf production was observed in VAD treated plants compared to C and CC, highlighting the superior nutrient bioavailability provided by VAD in accordance with SDG 2. The highest leaf count was recorded in the 5A VAD treatment, which can be attributed to its elevated concentrations of essential macronutrients, particularly calcium (Ca) and magnesium (Mg). VAD contains 2.392% Mg, which is 0.864% and 0.804% more than C and CC, respectively. In SD, Mg is 0.899 % and 0.809% more in C and CC, respectively. The abundance of Mg in VAD played a crucial role in chlorophyll synthesis, enzyme activation, and overall plant vigor, thereby enhancing leaf formation. Similarly, in the SD-treated plants, an increase in leaf count was observed relative to C and CC, demonstrating the positive impact of dolomite on plant growth. Among the SD treatments, the highest number of leaves was recorded in 3a, which contained an optimal balance of plant-available nutrients. Magnesium's role in photosynthesis and protein synthesis likely contributed to the increased leaf production observed in the 3a SD treatment. Magnesium (Mg) is a crucial macronutrient responsible for maintaining leaf health and facilitating numerous physiological and biochemical processes in plants. It plays a key role in sucrose transport, energy metabolism, nitrogen assimilation, and plant-soil microbial interactions, all of which contribute to overall plant vigor and productivity. Additionally, Mg is essential for the biosynthesis of calcium pectinate and adenosine triphosphate (ATP), which are integral to cell wall cohesion and structural integrity. In photosynthetic pathways, Mg is indispensable for the formation of chlorophyll (Chl) pigments, which enable CO_2 fixation and light absorption in chloroplasts. However, only 15–35% of the total Mg uptake is incorporated into chlorophyll pigments, while the remaining 65–85% is allocated to protein synthesis, enzyme activation, and other essential metabolic functions. Furthermore, Mg serves as a cofactor for over 300 enzymes, including those directly involved in photosynthetic CO_2 fixation and chlorophyll biosynthesis, thereby reinforcing its pivotal role in plant metabolism. Magnesium (Mg) is essential for the activation of various enzymes critical to plant metabolism, including adenosine triphosphatases (ATPases), glutathione synthase, RNA polymerases, protein kinases, phosphatases, and carboxylases. Its involvement in nitrogen metabolism directly influences protein synthesis, as higher Mg uptake is correlated with increased protein levels in both root and shoot tissues. The Mg present in value-added fertilizer (VAD) functions as a key enzymatic activator in protein and carbohydrate metabolism, enhancing plant growth and development. In addition to its role in enzymatic activation, Mg, along with potassium (K), plays a pivotal role in photosynthetic and respiratory processes. These elements act as structural components of chlorophyll and serve as cofactors for multiple enzymes involved in RNA and DNA synthesis, further supporting cellular growth and function. The calcium (Ca) content in VAD shows a significant increase of 0.965% compared to CC and 0.5% compared to C, underscoring its critical role in leaf development and overall plant growth. Calcium is actively involved in metabolic pathways that regulate nutrient uptake, influencing plant vigor and productivity. In VAD amended soil, Ca contributes to cell membrane stability and structural integrity by reinforcing cell wall architecture, which enhances the mechanical strength of plant tissues. Due to its low mobility within plant tissues, calcium is primarily absorbed through the root system during the early stages of growth, where uptake occurs rapidly and linearly. Consequently, early-stage application of Ca-enriched amendments, such as VAD, is crucial for cell wall stabilization and membrane integrity preservation. Calcium is also required for the formation of the middle lamella, a pectin-rich structure that cements adjacent plant cells together. Therefore, meristematic zones in roots, stems, and leaves, which undergo continuous cell division, are particularly susceptible to calcium deficiency due to the high demand for Ca in these actively growing tissues. As plants approach maturity, a notable decline in calcium concentration is often observed, likely due to redistribution and metabolic shifts. This highlights the importance of adequate Ca availability throughout the growth cycle to sustain optimal plant development and structural integrity. Calcium (Ca) plays a pivotal role in plant disease resistance by fortifying cell walls against pathogen-secreted hydrolytic enzymes, which degrade structural components of plant tissues. The high Ca concentration in soil treated with value-added fertilizer (VAD) enhances leaf development and overall plant resilience. Beyond structural support, Ca stabilizes cell membranes by interacting with phosphate groups and carboxylic acid residues in phospholipids and proteins, ensuring their optimal positioning near the membrane surface. This stabilization is essential for membrane integrity, selective permeability, and cellular signaling. Additionally, phosphorus (P) is fundamental to new tissue formation, cell division, and complex energy transduction pathways within the plant, influencing key metabolic functions. Iron (Fe), a crucial component of cytochromes, plays a role in electron transport chains, directly impacting plant transpiration and respiration. Fe also facilitates chlorophyll biosynthesis, which is integral to photosynthetic efficiency. Similarly, manganese (Mn) regulates photosynthetic activity and oxidation-reduction reactions, ensuring efficient energy conversion and metabolic balance. The higher nutrient composition of VAD, particularly its enhanced sulfur (S) content, further contributes to increased leaf formation and plant growth by supporting protein synthesis, enzymatic activity, and structural development. The synergistic effect of these elements in VAD treated soil results in improved plant vigor, nutrient uptake, and overall physiological performance.

Crop Yield

Crop yield, a fundamental metric for assessing agricultural productivity, is directly influenced by the plant's flowering and fruiting capacity. Table-6 presents the crop yield data; Fig.-7 compares the average number of flowers that successfully developed into fruits across all the treatments. To further assess yield performance, the fruit weight was measured and statistically analyzed against the control and experimental treatments. The findings indicate that the 5A treatment exhibited the highest flowers transitioning into fruits. This can be attributed to the enhanced nutrient availability facilitated by the incorporation of vermicompost enriched with converted mineral waste, which significantly boosted both fruit set and fruit biomass accumulation. The observed increase in crop yield is likely due to the improved plant nutrient assimilation resulting from macro- and micronutrient enrichment in the value-added fertilizer. The integration of transformed mineral waste into vermicompost not only enhanced soil fertility but also optimized nutrient bioavailability, leading to higher fruit production and improved fruit quality. These findings underscore the potential of value-added fertilizers in enhancing agricultural output and sustainability. The role of macronutrients and micronutrients in plant nutrition is crucial for achieving higher crop yield and quality. A balanced application of these nutrients significantly enhances the physiological efficiency of plants, leading to improved flowering, fruit set, and overall productivity. The early transition of plant structures from the vegetative to reproductive phase can be attributed to the efficient uptake of nutrients, which facilitates the synchronized transport of growth-promoting hormones, such as cytokinins, to axillary buds, thereby breaking apical dominance and inducing early flowering. Moreover, the combined application of organic and mineral fertilizers not only improves soil structure but also enhances soil fertility, leading to increased crop yield. Statistical analysis reveals that the 3a SD treatment exhibited the highest number of flowers, with a substantial proportion of those flowers successfully developing into fruits. The application of simple dolomite (SD) was observed to significantly increase fruit weight, thereby enhancing overall crop productivity and fruit quality. This yield improvement can be attributed to the enhanced nutrient availability and uptake efficiency associated with SD. The dolomite powder's macro- and micronutrient composition plays a pivotal role in improving soil fertility and plant metabolic functions, leading to better crop performance. The optimized nutrient supply from varying SD dosages likely contributed to higher reproductive success and greater biomass accumulation in treated plants. The development of flowers and fruits in plants depends on a balanced supply of essential nutrients, including nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), and sulfur (S). Soil pH variations and nutrient imbalances or deficiencies can significantly impact flowering and fruit set. The application of value-added fertilizer (VAD) modifies the physicochemical properties of the soil, ensuring a balanced nutrient profile, which in turn promotes flowering. Additionally, micronutrients play a crucial role in flower and fruit formation. For instance, magnesium (Mg) contributes to male fertility, pollen production, and stress tolerance, while potassium (K) is essential for fruit and flower development and disease resistance. Potassium also plays a vital role in regulating water uptake by the roots and its transpiration through leaves. A high phosphorus (P) level supports early and uniform crop maturation by facilitating the systemic transport of the florigen hormone. Florigen, a mobile flowering signal produced in the leaves, is transported via the phloem to the shoot apical meristem (SAM), where it triggers flowering gene expression. In this process, calcium ions (Ca^{2+}) bind to calmodulin (CaM), initiating the Ca^{2+}/CaM signaling pathway, which in turn activates the expression of G1 mRNA (or FT and CO mRNA). The accumulation of G1 mRNA (or GI-CO-FT mRNA) throughout the day leads to floral induction. Due to its high calcium content, VAD enhances early flowering compared to control (C), simple dolomite (SD), and compost control (CC). Among all treatments, 5A VAD exhibits the highest flower production, further reinforcing the positive impact of VAD on reproductive growth following the SDG 2.

Biomass

Figure-8 shows the biomass data of okra plants for C, CC, SD, and VAD. When the percentage of plant biomass was compared, there was a noticeable difference between the plants grown in untreated soil and those treated with CC, SD, and VAD. The rise in the levels of macronutrients, micronutrients, and growth hormone necessary for the plant's optimal growth is responsible for the increase in biomass of the plants treated with VAD. The variations in okra growth, yield, and fruit quality could be attributed to variations in their genetic structure. Value-added fertilizers, on the other hand, can provide a variety of nutrients and enhance the physical and biological characteristics of the soil, increasing the uptake of vital nutrients and decreasing nutrient losses. This, in turn, improves fertilizer use efficiency and raises soil nutrient availability. Plants treated with dolomite powder had significantly more fruits overall, both in terms of quantity and mass (3a). The health and biomass of the crop are, in fact, influenced by several nutrient elements that are present in dolomite powder. The plants take up these available nutrients from the soil, which stimulates vegetative growth and productivity. The main factor for an increase in biomass is the presence of primary, secondary, essential, and micronutrients in dolomite. An increase in P has an impact on a number of plant functions, including photosynthesis, respiration, energy transmission and storage, cell division, and expansion. K is necessary for the absorption of water and the synthesis of plant sugar for human consumption. In this way, it encourages the growth of plants, roots, fruits, seeds, etc. Ca is essential for maintaining cell integrity and membrane stability. Magnesium activates a number of enzymes that are involved in the synthesis of nucleic acids found in chlorophyll molecules and the metabolism of carbohydrates. A phosphatic carrier is Mg^{2+}. Micronutrients are involved in many aspects of plant metabolism, including the growth of cell walls, respiration, photosynthesis, the production of chlorophyll, enzyme activity, nitrogen fixation, and reduction. The crop yield's quality and quantity were enhanced by the dolomite powder's inclusion of micronutrients such as Mn, Fe, and others. The higher biomass in 3a SD compared to C, CC, and other SD treatments is caused by all of these reasons. In all the treatments, 5A of VAD showed maximum biomass. In VAD, the abundance and availability of plant nutrients and their easy accessibility for plants was the reasons for the highest crop yield of VAD than all other treatments of soil. Therefore, it is clear that VAD improves overall plant growth, nutrition, and soil sustainability in an eco-friendly way by fulfilling SDG-2.

CONCLUSION

Dolomite powder is abundantly found in India and Rajasthan, and it is also very cheap. It is a very good source of Ca and Mg for the plants that require these elements in large amounts. Hence, to meet the nutritional requirements of the okra plant and ensure soil fertility, the dolomite powder was used as a soil amendment to boost crop yield. XRF analysis revealed that dolomite powder contains a variety of macro and micro plant nutrients. In the present study, dolomite powder was converted into value added fertilizer, which is a more plant accessible form, and its higher nutritional content was reported in XRF analysis. It

was revealed that in comparison to plain soil (C), soil with vermicompost (CC), and simple dolomite powder (SD), value-added fertilizer with soil (VAD) contains various plant-nutrient elements. Among C and CC, CC demonstrated better soil productivity and plant growth than C. Because 3a treatment had an adequate amount of nutrients, it had the highest levels of vegetative growth, crop production, and biomass among all SD treatments. Excessive application of dolomite powder (4a and5a treatment of SD) resulted in clogging of soil pores, drying up roots, and raises soil alkalinity. As a result, okra plant growth is not supported by these concentrations. Thus, it can be said that a very efficient method of meeting the nutritional requirements of okra plants and ensuring soil fertility is to recycle dolomite powder from into soil fertilizer and use it to improve crop yield. Okra plants benefit from calcium and magnesium, and this value-added fertilizer of dolomite is high in these elements. When applied to okra plants, VAD outperforms C, CC, and SD in terms of seed germination, plant height, leaf count, crop yield, and biomass. Due to the largest concentration of nutrients in the 5A treatment, it exhibited the highest levels of biomass, crop production, and vegetative growth across all VAD and other treatments.
Thus, it can be said that one of the best ways to address the dolomite powder into compost with value addition and use it to boost agricultural output. It will also support these industries economic expansion and offer a cost-effective means of meeting the crop's nutritional requirements without any harm to soil or ecosystem. Therefore, conversion of dolomite into its more valuable and plant accessible form is the best way to increase agricultural output by soil amendment in an eco-friendly manner by fulfilling sustainable development goals (SDG-2).

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CONFLICT OF INTERESTS

The authors declare that there is no conflict of interest.

AUTHOR CONTRIBUTIONS

The present work is related to *SDG-2: Zero Hunger*. All the authors contributed significantly to this manuscript, participated in reviewing/editing and approved the final draft for publication. The research profile of the authors can be verified from their ORCID ids, given below:

Meenakshi https://orcid.org/0000-0002-1468-770X
D. Parmar https://orcid.org/0009-0008-2447-8486
B. Pal https://orcid.org/0009-0009-3385-468X
M. Choudhary https://orcid.org/0009-0006-9584-0206
M. Jat https://orcid.org/0009-0001-8221-5472

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