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Efficiency of granite rock dust combined with panchagavya, jeevamrutha and bio-enriched press mud compost as potassium source on growth and yield parameters of maize plants

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Abstract
A field experiment was carried out during 2021 and 2022 growing season in Ramagiri, Holalkere Taluk, Chitradurga district, Karnataka, India to evaluate the effect of co-application of granite rock dust, an M-Sand industry waste with panchagavya, jeevamrutha and bio-enriched press mud compost as potassium source on growth and yield parameters of maize plants. Several treatments combinations were evaluated *viz*., T_1 - Absolute control, T_2 - 100% RDK, T_3 - 75% RDK +Rock dust @ 6 t ha^{-1},T_4 - 75% K + Rock dust @ 3 t ha^{-1}, T_5 - 50% K + Rock dust @ 6 t ha^{-1}, T_6 - 50% K + Rock dust @ 3 t ha^{-1}, T_7 - 75% K + Jeevamrutha treated Rock dust @ 6 t ha^{-1}, T_8 - 50% K + Jeevamrutha treated Rock dust @ 3 t ha^{-1}, T_9 - 75% K + Panchagavya treated Rock dust @ 6 t ha^{-1}, T_{10} - 50% K + Panchagavya treated Rock dust @ 3 t ha^{-1}, T_{11} - 75% K + Bio-enriched press mud compost treated Rock dust @ 6 t ha^{-1}, T_{12} - 50% K + Bio-enriched press mud compost treated Rock dust @ 3 t ha^{-1}. Out of the different combinations of treatments, the treatment T_{11} found best with higher plant height (273.65 cm), number of leaves (15.53), cob length (18.81 cm), number of rows per cob (16.57), kernels per row (35.93), seed index (33.83 g) than compared to the treatment T_1 and T_2. In turn significantly, higher kernel (87.63q ha^{-1}) and stover yield (120.99q ha^{-1}) was also noticed in the treatment having 75% K + Bio-enriched press mud compost treated Rock dust @ 6 t ha^{-1} followed by treatment T_9 (75% K + Panchagavya treated Rock dust @ 6 t ha^{-1}) while the lowest ones were found in control treatment. Whereas, the treatments having combined application of granite rock dust with organic manures found best than compared to the treatments having granite rock dust only. This shows the efficiency of combined application of granite rock dust with different organic manures in enhancing the growth and yield of maize.

Keywords: Granite rock dust, bio-enriched press mud compost, panchagavya, jeevamrutha, FYM, maize production

Introduction
Maize (*Zea mays* L.) Is a cereal of high economic relevance and a variety use ranging from food and feed to the high-technology industries? Potassium (K) is one of the macronutrient essential for maize growth and plays an important role in plant growth, metabolism and development. Without adequate potassium, the plants will have poorly developed roots, grow slowly, produce small seeds and have lower yields. Soluble potassium in soils is frequently not sufficient for high production of maize, although most soils have high contents of insoluble forms of potassium (Sheng and Huang, 2002) [22]. In India, farmers apply high rates of chemical potassium fertilizers (such as sulphates and chlorides of potassium) to maize. The high price of chemical fertilizers contributes to increasing production cost of crops, which may be one of the reasons for us aiming at providing plants with K released from mineral non-soluble sources (Manning, 2010 and Labib *et al*., 2012) [18, 16]. The use of local M-Sand industry waste product i.e., granite rock dust (it's a pulverized stone, often produced as a by-product of the mining and crushing industries), which is composed of different minerals containing considerable amount of potassium could be a better option in re-mineralizing the soil. The elements contained in the rock dust are become available upon weathering. There are few but consistent reports on the use of multi-nutrient rock and mineral fertilizers in the organic and conventional production systems (Fyfe *et al*., 2006) [9].
Organic waste, such as press mud or filter cake, is generated as a by-product of sugarcane industries and characterized as a soft, spongy, amorphous, and dark brown to brownish material (Ghulam *et al*., 2012) [10].

With the bio-enrichment of pressmud compost with different microbial cultures will enhance the product quality with respect to nutrient availability and microbial activity.

Panchagavya is one of the widely used traditional organic formulations, which is mostly prepared by farmers themselves. Panchagavya is a fermented product made from five ingredients obtained from cow, such as milk, urine, dung, curd and clarified butter (Amalraj *et al*., 2013) [1]. Recently, higher number of cultivable bacterial genera was obtained from the organic formulation prepared using fermented cow manure (Giannattasio *et al*., 2013) [11]. In addition, few novel and plant growth-promoting bacteria such as *Larkin ella bovis* and *Mycobacterium Womens* were isolated from traditional organic formulations and tested for their plant growth promotion (Anandham *et al*., 2011a) [2].

Jeevamrutha is a plant growth-promoting substance containing beneficial microorganisms that provides the necessary nutritional requirement for growth and yield of a crop. The microorganisms that supply nitrogen like Azotobacter, Acetobacter, *Azospirillum* and phosphorus-solubilizing bacteria like *Pseudomonas* and potash-solubilizing bacteria like *Bacillus silicus* are present in dung that is used to prepare jeevamrutha. Microorganisms are well activated in soil following the addition of jeevamrutha which also maintains soil productivity (Vanaja *et al*., 2009) [26].

In view of the above, the current study focused on evaluating the Efficiency of granite rock dust combined with panchagavya, jeevamrutha and bio-enriched press mud compost as potassium source on growth and yield parameters of maize plants.

Material and Methods

A field experiment was carried out during 2021 and 2022 growing season by using maize as a test crop (MAH-14-5) in Ramagiri, Holalkere Taluk, Chitradurga district, Karnataka, India to study the asses of the efficiency of K fertilization (K containing granite rock dust combined with solid and liquid organic manures) to maize (*Zea mays* L.). The physical and chemical properties of soil were determined according to standard protocols as given in the Table 1.

Table 1: Methods adopted for soil analysis

Parameters	Method	Reference
Physical properties		
Texture	International Pipette method	Piper (1966) [20]
MWHC (%)	Keen's cup	Piper (1966) [20]
P.D g/cc	Keen's cup	Piper (1966) [20]
B.D g/cc	Keen's cup	Piper (1966) [20]
Chemical properties		
pH (1:2.5)	Potentiometry	Jackson (1973) [15]
EC (dS m^{-1}) (1:2.5)	Conductometry	Jackson (1973) [15]
Organic Carbon (%)	Wet oxidation method	Walkley and Black (1934) [29]
Cation Exchange Capacity [cmol (p^+) kg^{-1} of soil]	Ammonium acetate leaching method	Jackson (1973) [15]
Avail. N (kg ha^{-1})	Alkaline potassium permanganate distillation method	Subbiah and Asija (1956) [25]
Avail. P_2O_5 (kg ha^{-1})	Olsen's extract ant method, Colorimetry using ascorbic acid reagent	Jackson (1973) [15]
Avail. K_2O (kg ha^{-1})	Ammonium acetate extract ant method, Flame photometry	Jackson (1973) [15]
Exch. Ca and Mg [cmol (p^+) kg^{-1}]	Ammonium acetate extract ant method, Versenate titration method	Jackson (1973) [15]
Avail. S (mg kg^{-1})	$CaCl_2$ extract ant method, Turbidimetry	Black (1965) [6]
DTPA extractable Fe, Mn, Zn and Cu (mg kg^{-1})	Atomic absorption spectrophotometry	Lindsay and Norvell (1978) [17]
Microbial population		
Bacteria	Serial dilution technique	Waksman (1927) [27]
Actinomycetes	Serial dilution technique	Waksman (1927) [27]
Fungi	Serial dilution technique	Waksman (1927) [27]
Dehydrogenase activity (µg TPF g^{-1} soil hr^{-1})	Triphenyl tetrazolium chloride (TTC) technique	Casida *et al*. (1964) [7]

The site I was sandy clay in texture with 47.16, 15.37 and 37.47 per cent sand, silt and clay, respectively and bulk density, particle density and maximum water holding capacity of the soil was 1.21Mg m^{-3}, 2.65 Mg m^{-3} and 44.96 per cent, respectively. The soil was neutral in reaction (pH 7.22) and low in soluble salts (0.16dS m^{-1}).The soil was medium in organic carbon (5.80g kg^{-1}), low in available nitrogen (278.47 kg ha^{-1}), medium in available P_2O_5 (33.10 kg ha^{-1}),medium in available K_2O (254.32 kg ha^{-1}) and water soluble, exchangeable and non-exchangeable potassium were 29.34, 138.28 and 270.08 mg kg^{-1}, respectively. While the sulfur content (14.20 mg kg^{-1}) was sufficient. The exchangeable calcium and magnesium content of soil was 4.72 and 3.12 cmol (p^+) kg^{-1}, respectively. The content of DTPA extractable iron, manganese, zinc and copper was 12.75, 7.84, 0.80 and 0.65 mg kg^{-1}, respectively. The dehydrogenase activity was 8.05 µg TPF g^{-1} soil hr^{-1}.

The site II was sandy clay in texture with 46.19, 16.20 and 37.61 per cent sand, silt and clay, respectively and bulk density, particle density and maximum water holding capacity of soil was 1.17Mg m^{-3}, 2.52 Mg m^{-3} and 45.19 per cent, respectively. The soil was neutral in reaction (pH 7.24) and low in soluble salts (0.17dS m^{-1}).The soil was medium in organic carbon (5.92g kg^{-1}), medium in available nitrogen (285.21 kg ha^{-1}), medium in available P_2O_5 (42.94 kg ha^{-1}), medium in available K_2O (265.25 kg ha^{-1}) and water soluble, exchangeable and non-exchangeable potassium were 34.83, 142.98 and 275.24 mg kg^{-1}, respectively. The exchangeable calcium and magnesium content of soil was 4.18 and 2.92cmol (p^+) kg^{-1}, respectively, while the available sulphur content was sufficient (13.21 mg kg^{-1}).The content of DTPA extractable iron, manganese, zinc and copper was 10.13, 7.95, 0.68 and 0.61 mg kg^{-1}, respectively. The dehydrogenase activity was 10.51µg TPF g^{-1} soil hr^{-1}.

The granite rock dust collected from local M-stand industry was treated with panchagavya or jeevamrutha, bio enriched press mud compost or farm yard manure in the ratio of 10:1:2, respectively(*i.e.*, the treatments with liquid organic manure, for every 10 parts of rock dust, 1 part of panchagavya or jeevamrutha along with 2 parts of farm yard manure as a carbon source was added and the treatments with solid organic manure, for every 10 parts of rock dust, 2 parts of bio-enriched press mud compost was added). The bio treated rock dust was kept for curing for fifteen days and then that was added to field along with recommended dose of FYM fifteen days prior to sowing of maize. The recommended dose of fertilizers [150:75:40 (N, P_2O_5, K_2O kg ha^{-1}) + 10 kg $ZnSO_4$ ha^{-1} for irrigated condition] was applied at the time of sowing. The treatments details are as follows.

Treatments	Details
T_1	Absolute control
T_2	100% RDK
T_3	75% RDK +Rock dust @ 6 t ha^{-1}
T_4	75% K + Rock dust @ 3 t ha^{-1}
T_5	50% K + Rock dust @ 6 t ha^{-1}
T_6	50% K + Rock dust @ 3 t ha^{-1}
T_7	75% K + Jeevamrutha treated Rock dust @ 6 t ha^{-1}
T_8	50% K + Jeevamrutha treated Rock dust @ 3 t ha^{-1}
T_9	75% K + Panchagavya treated Rock dust @ 6 t ha^{-1}
T_{10}	50% K + Panchagavya treated Rock dust @ 3 t ha^{-1}
T_{11}	75% K + Bio-enriched press mud compost treated Rock dust @ 6 t ha^{-1}
T_{12}	50% K + Bio-enriched press mud compost treated Rock dust @ 3 t ha^{-1}

Note: 100% Recommended dose of (RD) -N, P and Zn is common for all the treatment except T_1,
Recommended dose of FYM is used for all the treatments except T_1, T_{11} and T_{12}
FYM- Farm Yard Manure, POP- Package of Practice,
Recommended package of practices as per the UAS B package of practices includes application of recommended dose of NPK for Maize is 150:75:40 kg ha^{-1} + 10 kg ha^{-1} $ZnSO_4$, with farm yard manure (FYM) at the rate of 10 t ha^{-1}.

Growth parameters

The periodic growth observation with respect to plant height and number of leaves were taken at 30, 60, 90 DAS and at harvest from the tagged plants.

Plant height (cm)

The plant height of tagged plants in each net plot was measured from base of the plant to the base of the fully opened top leaf until tassel emergence. Later, the plant height was measured from the base of the plant to the tip of the main flag leaf. The average of five plants was taken as plant height and expressed in centimeter.

Number of leaves

The number of leaves produced per plant was recorded by counting the fully opened leaves of five tagged plants and their average was worked out.

Yield parameters

Five cobs were randomly taken from the tagged plants in net plot and mean of the five plants observation were recorded. The techniques used and details of the observations recorded are explained in the following paragraphs.

Cob length (cm)

To get the mean cob length of respective treatment, five cobs were selected from previously labelled plants and measured from the base to the tip of the cob, the mean was taken as cob length and expressed in centimeters.

Number of kernel rows per cob

The average number of kernel rows per cob was worked out by counting the total rows from each cob of five labelled plants.

Number of kernels per row

The number of kernels per row was counted in each cob of five labelled plants.

Seed index (g)

Hundred grains were counted and the weight was recorded for each kernel samples drawn from each of the net plot and expressed in grams.

Kernel yield (q ha^{-1})

At physiological maturity cobs from each net plot was harvested. Cobs were dehulled, air dried, shelled, cleaned and weighed. Kernel yield ha^{-1} was worked out and expressed in q ha^{-1}.

Stover yield (q ha^{-1})

Stover yield was recorded after complete sun drying the stalks from each net plot and expressed in q ha^{-1}.

Economics

Cost of cultivation (Rs ha^{-1})

The price of inputs that were prevailing at the time of their use was considered to work out cost of cultivation. Treatment wise cost of cultivation was worked out. Net returns ha^{-1} was calculated by deducting the cost of cultivation from gross income ha^{-1}.

Benefit: cost (B: C) ratio

Benefit cost ratio was worked out by using the following formula.

$$\text{Benefit: cost ratio} = \frac{\text{Gross returns (Rs. ha}^{-1}\text{)}}{\text{Cost of cultivation (Rs. ha}^{-1}\text{)}}$$

Statistical analysis

The data collected from the experiment at different growth stages were subjected to statistical analysis as described by Gomez and Gomez (1984) [12] for drawing conclusions on the effect of various treatments on different parameters studied. The level of significance used in "F" was P = 0.05. Critical difference (CD) values were calculated for the P = 0.05 whenever "F" test was found significant. The two years (2020 and 2021) data were pooled, analyzed and results are presented in results and discussion section.

Results and Discussion

Growth parameters of maize

The data on plant height (cm) and number of leaves per plant of maize at different stages of crop growth period (30 DAS, 60 DAS, 90 DAS and at harvest) as influenced by the application of bio-treated granite rock dust are presented in Table 2 and 3.

Plant height

The data from the Table 2 it was revealed that, at 30 DAS after soil application of bio-treated rock dust recorded the significantly higher plant height of 83.64 cm in T_{11} (75% K + Bio-enriched press mud compost treated Rock dust @ 6 t ha^{-1}) which was on par with all other treatments except T_1 (Absolute control) and significantly lower plant height of 69.32 cm was recorded in control (T_1). The pooled data of plant height at 60 and 90 DAS indicated that, higher plant height of 174.70 and 268.19 cm, respectively was recorded in treatment T_{11}, which was on par with all other rock dust treated treatments and showed significant with the treatment T_2 (100% recommended dose of fertilizers) and T_1 (absolute control) however, the lower plant height was recorded in treatmentT_1 (133.02 and 217.48 cm, respectively).

The pooled data of plant height at harvest indicated that, significantly higher plant height of 273.65 cm was recorded in T_{11} (75% K + Bio-enriched press mud compost treated Rock dust @ 6 t ha^{-1}) which was on par with the treatment T_9 (75% K + Panchagavya treated Rock dust @ 6 t ha^{-1}). T_{12} recorded the plant height of 256.42 cm and that was on par with rest of the treatments except T_6 (242.10 cm) and T_1 (absolute control). However, the lower plant height was registered in treatment T_1 with 222.18 cm.

Table 2: Plant height (cm) at different growth stages of maize as affected by application of bio-treated granite rock dust

Treatments	30 DAS			60 DAS			90 DAS			Harvest		
	2020	2021	Pooled	2020	2021	Pooled	2020	2021	Pooled	2020	2021	Pooled
T_1	70.38	68.25	69.32	127.90	138.14	133.02	214.73	220.24	217.48	223.45	220.92	222.18
T_2	81.48	81.35	81.41	152.97	163.90	158.44	246.33	250.85	248.59	248.23	252.80	250.52
T_3	80.81	81.31	81.06	159.57	162.55	161.06	245.73	249.92	247.83	247.52	251.58	249.55
T_4	79.22	81.00	80.11	156.87	161.14	159.01	242.64	243.25	242.94	244.14	245.32	244.73
T_5	80.20	81.01	80.60	159.11	161.45	160.28	243.54	247.92	245.73	245.49	248.71	247.10
T_6	79.06	79.08	79.07	155.84	160.25	158.05	242.33	240.04	241.18	243.61	240.58	242.10
T_7	81.92	82.27	82.10	163.03	164.50	163.77	249.69	251.87	250.78	251.85	253.70	252.77
T_8	81.88	81.63	81.76	162.97	164.01	163.49	246.93	251.86	249.40	251.45	252.99	252.22
T_9	84.00	82.86	83.43	167.64	171.56	169.60	261.84	255.21	258.53	263.66	259.04	261.35
T_{10}	81.94	82.46	82.20	163.37	164.72	164.05	253.79	253.09	253.44	255.43	255.32	255.38
T_{11}	84.11	83.17	83.64	168.26	181.14	174.70	264.92	271.45	268.19	273.73	273.56	273.65
T_{12}	83.00	82.70	82.85	170.85	167.16	169.00	254.13	253.89	254.01	256.25	256.58	256.42
S.Em ±	2.37	2.62	1.88	7.19	6.51	5.52	7.89	7.62	6.47	7.84	7.40	4.37
CD @ 5%	6.95	7.68	5.51	21.10	19.10	16.20	23.15	22.37	19.00	23.01	21.71	12.82

Number of leaves per plant

The data on number of leaves are presented in Table 3 and from this table it was observed that, higher number of leaves per plant was recorded in the treatment T_{11} having 75% K + Bio-enriched press mud compost treated Rock dust @ 6 t ha^{-1}(7.60) and which was on par with all the granite rock dust treated treatments and treatment T_2 (100% RDK) but showed significant with the treatment T_3 (6.87) and lower number of leaves were recorded in control treatment T_1(4.97) at 30 DAS. At 60 DAS, significantly highest number of leaves per plant (13.77)was recorded in treatment T_{11},which was on par with all other treatments and showed significant with the treatment T_6 (12.53) and T_1 (10.75). At 90 DAS and at harvest, significantly highest number of leaves per plant (15.10 and 15.53, respectively) was recorded in treatment T_{11}, it was depicted on par with all other treatments and significant with treatment T_4 (13.87 and 14.47,respectively) but lowest number of leaves per plant was observed in T_1 (11.42 and 12.42, respectively).

Application of various rates of rock dust alone and bio treated rock dust had significantly increased the plant height and number of leaves per plant. Application of bio treated granite rock dust at both the levels (3 and 6 t ha^{-1}) showed significant effect on above parameters over absolute control and rock dust alone treated treatments but found on par with each other.

The increase in plant height and number of leaves by the application of bio-treated granite rock dust might be due to increased availability of macro and micro-nutrients over the period of time, which boosted the crop growth by better cell division, cell elongation and increased accumulation of photosynthates which in turn favoured the better plant growth and development (Panda *et al*., 2018) [19]. Ayanlowo *et al*. (2014) [3] reported that, combined application of granite dust and poultry manure at the rate 0.5 and 3 t ha^{-1}, respectively increased the growth of maize crop in Alfisol. Similarly, Hassan and Mohammed (2017) [13] reported that the application of gabbroic rock dust has improved the growth and yield of sesame, due to increased availability of Ca, Mg, K and Na in soil. Application of rock dust along with FYM two weeks before sowing of crop enhanced the available nutrient status in soil thus increasing the growth of maize. De Souza *et al*. (2013) [24] reported taller and heavier maize plants with application of vermicompost enriched with rock powder (gneiss or steatite powders @ 0, 5 and 20%) than plants fertilized with non-enriched vermicompost. These findings are in lines with those reported by Hinsinger *et al*. (1996) [14] in Wheat, Shamsuddin *et al*. (2011) [21] in Cocoa.

Table 3: Number of leaves at different growth stages as of maize affected by application of bio-treated granite rock dust

Treatments	30 DAS			60 DAS			90 DAS			Harvest		
	2020	2021	Pooled	2020	2021	Pooled	2020	2021	Pooled	2020	2021	Pooled
T_1	4.80	5.13	4.97	10.29	11.20	10.75	11.33	11.50	11.42	12.50	12.33	12.42
T_2	7.20	6.87	7.03	13.07	13.13	13.10	14.40	14.33	14.37	14.67	14.73	14.70
T_3	7.07	6.67	6.87	12.73	12.60	12.67	14.27	14.33	14.30	14.67	14.67	14.67
T_4	6.80	6.53	6.67	12.93	12.53	12.73	14.27	13.47	13.87	14.67	14.27	14.47
T_5	6.80	6.53	6.67	13.07	12.53	12.80	14.27	14.07	14.17	14.67	14.33	14.50

T_6	6.67	6.33	6.50	12.80	12.27	12.53	14.00	13.40	13.70	14.40	14.07	14.23
T_7	7.20	7.13	7.17	13.20	13.47	13.33	14.67	14.73	14.70	14.93	15.13	15.03
T_8	7.20	7.07	7.13	13.07	13.13	13.10	14.40	14.67	14.53	14.80	14.73	14.77
T_9	7.47	7.47	7.47	13.33	14.07	13.70	14.93	15.27	15.10	15.47	15.40	15.43
T_{10}	7.33	7.10	7.22	13.20	13.53	13.37	14.67	14.73	14.70	15.07	15.13	15.10
T_{11}	7.73	7.47	7.60	13.47	14.07	13.77	14.93	15.27	15.10	15.60	15.47	15.53
T_{12}	7.47	7.47	7.47	13.20	13.53	13.37	14.80	14.73	14.77	15.07	15.13	15.10
S. Em±	0.32	0.31	0.22	0.54	0.53	0.38	0.58	0.59	0.38	0.48	0.48	0.35
CD @ 5%	0.95	0.92	0.67	1.58	1.57	1.12	1.70	1.74	1.13	1.42	1.41	1.04

Effect of bio-treated granite rock dust application on yield parameters of maize

The data on cob length (cm), number of rows per cob, number of kernels per row, seed index (g) at harvest as influenced by different rates of bio-treated granite rock dust application are presented in Table4. Though the application of bio-treated granite rock dust influenced these parameters positively yet the effect was different in each of these parameters.

Cob length (cm)

Pooled analysis of experimental data with respect to cob length from the Table 4, it was observed that, higher cob length of 18.81 cm was recorded in T_{11} and it was on par with rest of the treatments having rock dust and treatment which is having 100% recommended dose of fertilizers along with FYM.

Number of rows per cob

The pooled analysis revealed that, number of rows per cob varied significantly due to imposition of treatments. The values of rows per cob was ranged from 16.57 to 11.67. However, the highest number of rows per cob was recorded in T_{11} (16.57) and it was statistically at par with all other treatments where application of bio-treated rock dust and non-bio-treated rock dust used. But the least number of rows per cob was recorded inT_1 (11.67).

Number of kernels per row

Pooled data of number of kernels per row indicated that, significantly higher number of kernels per row was recorded in T_{11} (35.93) compared to all the treatments tested except the treatment T_9 (34.83). Least number of kernels per row was recorded in T_1 (22.42).

Seed index (g)

As indicated in Table 4, seed index varied significantly in all the treatments. The pooled data indicated that, higher seed index (33.83 g) was noticed in the treatment T_{11} and it was on par with the treatment T_9 (33.50 g), T_{10} (32.33 g) and T_{12} (32.67 g) but showed significant results with rest of the treatments. Lowest seed index value (26.33 and 27.17 g, respectively) was recorded in the treatmentT_4 and in control treatment T_1.

The application of bio-treated granite rock dust had the positive and significant effect on the above studied yield parameters. The improvement was due to the enhanced metabolic activity of plants that helps in flower initiation in tassel and silk initiation in maize and also overcoming from the soil fertility constraints with increased availability of nutrients over a longer period of time for crop uptake (Chathurika *et al*., 2015) [8]. Synthesis of organic compounds increased by increased photosynthesis due to increased nutrient availability. Plants use these organic compounds (Starch, monosucrose, protein and vit-A & vit-C) for cell division and multiplication that in turn resulted in increased yield and quality of potatoes (Labib *et al*., 2012) [16]. Weerasuriya *et al.* (1993) [28] reported that application of acidulated pegmatitic mica (@ 200 kg ha^{-1}) increased the panicle number (32%) and seed weight (41%) in rice. Similar findings were reported by Silva *et al*. (2013) [23] in Italian ray grass.

Table 4: Yield attributes of maize as influenced by application of bio-treated granite rock dust

Treatments	Cob length (cm)			No. of rows per cob			Kernels per row			Seed index (g)		
	2020	2021	Pooled	2020	2021	Pooled	2020	2021	Pooled	2020	2021	Pooled
T_1	13.87	14.01	13.94	11.24	12.10	11.67	22.60	22.23	22.42	26.67	26.00	26.33
T_2	17.75	17.84	17.80	15.60	15.81	15.71	29.27	30.67	29.97	30.33	31.33	30.83
T_3	17.58	17.69	17.64	15.47	15.63	15.55	29.20	30.27	29.73	30.67	31.00	30.83
T_4	17.40	17.33	17.36	14.67	14.83	14.75	26.13	27.4	26.77	27.33	27.00	27.17
T_5	17.41	17.62	17.52	14.80	15.33	15.07	26.53	28.27	27.40	29.00	29.33	29.17
T_6	17.11	17.25	17.18	14.33	14.80	14.57	25.67	26.73	26.20	27.00	26.67	26.83
T_7	18.13	18.22	18.18	15.73	16.07	15.90	29.93	31.27	30.60	30.67	32.33	31.50
T_8	18.01	18.00	18.01	15.53	15.93	15.73	29.87	29.87	29.87	29.67	29.67	29.67
T_9	18.55	18.89	18.72	16.43	16.47	16.45	34.60	35.07	34.83	33.33	33.67	33.50
T_{10}	18.23	18.42	18.32	15.93	15.80	15.87	32.60	31.47	32.03	32.33	32.33	32.33
T_{11}	18.62	19.00	18.81	16.60	16.53	16.57	35.60	36.27	35.93	33.67	34.00	33.83
T_{12}	18.26	18.57	18.41	16.07	16.13	16.10	32.93	32.40	32.67	32.67	32.67	32.67
S.Em±	0.83	0.76	0.59	0.65	0.74	0.60	1.21	1.25	0.93	1.61	1.45	1.01
CD @ 5%	2.44	2.23	1.74	1.91	2.17	1.77	3.55	3.66	2.72	4.72	4.25	2.97

Effect of bio-treated granite rock dust application on kernel and stover yield (q ha^{-1}) of maize

The data on kernel and stover yield of maize as influenced by application of graded levels of bio-treated granite rock dust are presented in Table 5.

The pooled analysis indicated that, kernel yield of 87.63 q ha^{-1} was recorded in $T_{11}$and second highest kernel yield (79.59q ha^{-1}) was recorded in the treatment $T_9$and it was on par with the treatment T_{12} (77.08 q ha^{-1}) and T_{10} (74.67q ha^{-1}). In case of jeevamrutha treated rock dust treatment (T_7) kernel yield of 68.89 q ha^{-1}was recorded and it was on par with the treatment T_8 (66.24q ha^{-1}), T_2 (65.57q ha^{-1}), T_3 (65.39q ha^{-1}) and T_5 (63.67q ha^{-1}) but in the treatments (T_4 and T_6) where rock dust application @ 3 t ha^{-1} along with FYM were used recorded significantly higher kernel yield of 57.51 and 56.38q ha^{-1}, respectively compared to the control treatment $T_1$38.78q ha^{-1}.

The pooled analysis of stover yield indicated that, the highest stover yield of 120.99 q ha^{-1} was recorded in T_{11} and second highest stover yield (108.23 q ha^{-1}) was recorded in the treatment $T_9$and it was on par with the treatment T_{12} (103.80 q ha^{-1}) and T_{10} (100.98q ha^{-1}). In case of jeevamrutha treated rock dust treatment (T_7) recorded stover yield of 94.24 q ha^{-1} and it was on par with the treatment T_8 (91.92q ha^{-1}), T_2 (92.93q ha^{-1}),T_3 (92.80q ha^{-1}) and T_5 (88.85q ha^{-1}).But in the treatments with rock dust application @ 3 t ha^{-1} along with FYM (T_4 and T_6) recorded significantly higher stover yield of 80.55 and 80.43q ha^{-1}, respectively compared to the control treatment T_1 (59.35q ha^{-1}).

The significant increase both in kernel and stover yield of maize with the application of 75% RDK + Bio-enriched press mud compost treated Rock dust @ 6 t ha^{-1}may be attributed to improvement in growth parameters *viz*., plant height and number of leaves (Table 14 and 15) and yield parameters *viz.*, cob length, number of rows per cob, number of kernels per row, seed index and harvest index (Table 16 and 17) with the bio-treated granite rock dust application. The yield of crop may be the manifestation of climate and soil condition. Application of bio-treated granite rock dust improved the availability of nutrients as consequence of release of nutrients from the added rock dust might have influenced the growth and yield of maize. The nutrient element contained in the rock dust is made available slowly upon dissolution of minerals as it is applied with FYM besides the organic acids that are released by roots caused the dissolution (Barker *et al*., 1998) [5] and thus releasing the nutrients in slow and sustained manner that has helped in getting higher yield in maize. The increase in yield of maize might be attributed to the supply of readily soluble form of nutrients supplied through urea, SSP and MOP and slow releasing source, rock dust. These findings are in line with those reported by Chathurika *et al.* (2015) [8]. They recorded a significant increase in yield of maize with the application of rock powder + site specific fertilizer over the control during two years of experimentation (2013 and 2014) due to correction of soil fertility constraints in soil.

The increase in yield might also be due to improvement in nutrient uptake and biological property of the soil. These inferences are well supported by the findings of Weersuriya *et al*. (1993) [28] and Badr (2006) [4]. Weerusuriya *et al*. (1993) [28] reported an increase in the grain yield of rice due to application of acidulated pegmatitic mica along with RDF and dolomite. The increase in yield was attributed to the release of nutrients by dissolution from pegmatitic mica as it is acidulated. Similarly, Badr (2006) [4] reported that feldspar enriched compost application along with silicate dissolving bacteria improved the yield of tomato due to increase in the bioavailability of nutrients from the added feldspar enriched compost.

The yield of maize increased with increasing level of bio-treated granite rock dust application and the highest yield was obtained with higher dose (6 t ha^{-1}) of rock dust application. These results are in conformity with those reported by Silva *et al*. (2013) [23]. They have reported that the yield of Italian ryegrass increased significantly with increasing granitic powder doses in comparison to the other amendments.

Table 5: Kernel and stover yield (q ha^{-1}) as influenced by application of bio-treated granite rock dust in maize

Treatments	Kernel yield (q ha^{-1})			Stover yield (q ha^{-1})		
	2020	2021	Pooled	2020	2021	Pooled
T_1	39.80	37.76	38.78	60.77	57.94	59.35
T_2	64.58	66.56	65.57	92.36	93.51	92.93
T_3	64.07	66.72	65.39	91.86	93.73	92.80
T_4	57.09	57.92	57.51	80.07	81.03	80.55
T_5	62.34	65.00	63.67	88.02	89.68	88.85
T_6	56.82	55.94	56.38	81.01	79.85	80.43
T_7	67.06	70.72	68.89	93.41	95.07	94.24
T_8	64.85	67.63	66.24	91.44	92.40	91.92
T_9	78.81	80.37	79.59	107.48	108.98	108.23
T_{10}	73.13	76.21	74.67	100.62	101.34	100.98
T_{11}	86.77	88.49	87.63	119.98	122.00	120.99
T_{12}	76.75	78.09	77.08	104.26	103.35	103.80
S.Em±	2.17	2.22	2.08	4.04	3.52	3.70
CD @ 5%	6.35	6.51	6.10	11.84	10.33	10.85

Economics

Economics of maize production (mean of 2020 and 2021) as influenced by bio-treated granite rock dust application is presented in Table 6.Higher cost of cultivation was recorded in T_9 (Rs. 66659.60) followed by T_{11} (Rs. 66539.60) and lower cost of cultivation was observed in T_1 (Rs. 45250.00). Higher net return was observed in T_{11} (Rs.109926.39) followed by T_9 (Rs.93599.26). Lower net return was obtained in T_1 (Rs.32903.60). Higher B: C ratio of 2.65 was recorded in T_{11} treatment followed by T_{12} (2.43) and T_9 (2.40). Lower B: C ratio of 1.73 was obtained in control treatmentT_1.Higher B: C ratio in treatment $T_{11}$was mainly attributed to higher kernel yield and stover yield. The B:C ratio obtained in T_7, T_8, T_9, T_{10}, T_{11} and T_{12} was more than that of the 100% recommended package of practice alone which suggests reduced dosage of inorganic fertilizer which help in reducing the cost of cultivation.

Table 6: Economics (mean of 2020 and 2021) of maize production as influenced by bio-treated granite rock dust application

Treatments	COC	Gross returns	Net returns	B:C
T_1	45250.00	78153.60	32903.60	1.73
T_2	63380.00	132072.73	68692.73	2.08
T_3	63893.60	131714.88	67821.28	2.06
T_4	63486.05	115817.06	52331.01	1.82
T_5	63592.10	128224.67	64632.57	2.02
T_6	63184.55	113584.30	50399.75	1.80
T_7	64463.60	138718.65	74255.05	2.15
T_8	63469.55	133395.76	69926.21	2.10
T_9	66659.60	160258.86	93599.26	2.40
T_{10}	64567.55	150348.42	85780.87	2.33
T_{11}	66539.60	176465.99	109926.39	2.65
T_{12}	63904.55	155205.02	91300.47	2.43

Conclusion

Rock dust, a waste generated from M-Sand industry can be used for improving growth and yield of maize. The present study confirmed that the bio-intervention of granite rock dust with locally available or self-prepared solid and liquid organic manures will enhance the release rate of nutrients through various mechanisms. From the results obtained, it can be concluded that the treatments with bio-treated granite rock dust *viz*., T_7 (75% K + Jeevamrutha treated Rock dust @ 6 t ha^{-1}), T_8 (50% K + Jeevamrutha treated Rock dust @ 3 t ha^{-1}), T_9 (75% K + Panchagavya treated Rock dust @ 6 t ha^{-1}), T_{10}

(50% K + Panchagavya treated Rock dust @ 3 t ha^{-1}), T_{11} (75% K + Bio-enriched press mud compost treated Rock dust @ 6 t ha^{-1}) and T_{12} (50% K + Bio-enriched press mud compost treated Rock dust @ 3 t ha^{-1}) were found better in terms of improving the performance of maize and soil properties along with increased release of potassium from rock dust besides higher economic returns than treatments with non-bio-treated granite rock dust. But among those treatments with the application of bio-treated granite rock dust treatment T_{11} was found best followed by T_{12} and T_9 in all the aspects of maize cultivation.

Hence application of recommended NP (@ 150 and 75 kg ha^{-1}) along with 75 per cent K and bio-enriched press mud compost treated rock dust (@ 6 t ha^{-1}) may be recommended. This enables recycling of resources and environmental concerns.

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