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Research Article

Chronosequence variation in soil properties of sandstone quarry spoil surrounding Aizawl, Mizoram and its impact on the growth of *Coriandrum sativum*

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Abstract
Sandstone quarrying is a major income-generating enterprise inAizwalCity of Mizoram, India. The by-product, sandstone dust, is dumped near the mining area, potentially affecting soil and water quality. The present study seeks to understand the soil development process over time by analyzing soil parameters in chronosequence, *viz.* fresh, 2-year, 4-year, 6-year, 8-year, 10-year, and 12-year-old dumps, and evaluating growth parameters of *Coriandrum sativum* (Coriander) in soils of different ages under greenhouse conditions. The soil moisture content of the soil increased with the age of the soil and freshly dumped sandstone quarry spoil had the highest levels of pH (7.7) and electrical conductivity (13.16 dS/m), which dramatically dropped to 5.4 and3.45dS/m, respectively, as the soil grew older. Other soil qualities, which included water-holding capacity, soil organic carbon (from 0.46%-0.78%), available nitrogen (from 38kg/ha-217.33kg/ha), and available potassium (from11kg/ha-22kg/ha) also improved with age. Although significant variation was observed in germination parameters among dumps of various ages, germination was not deterred in fresh dumps. Growth parameters improved as the soil matured, with maximum values observed at 12 the old dump. However, the slow development of coriander, even after 12 years, indicates that soil amendment techniques should be used to accelerate the recovery of plant attributes and eco-restoration of such sites.

Keywords: Coriander, Germination, Mining, Mizoram, Reclamation

INTRODUCTION

Natural resources are the foundation of human development. Although there is a realization that natural resources across the globe are quickly depleted, our dependency on them has stretched even more. With increasing demand for stone for construction activities, there has been a surge in the number of quarries and the intensity at which these quarries operate. Sandstone is one of the geological minerals that is a very popular construction material. China, India, Italy, Poland, South Africa, Romania, Hungary and Vietnam are the largest producers of sandstone (Agrawal and Gaharwar, 2013). There is no comprehensive inventory of sandstone, but the Centre for Development of Stones (CDOS), a 'Government of Rajasthan Undertaking' has reported estimated sandstone reserves at over 1,000 million tonnes in the country (Indian Minerals Yearbook, 2020). Although the activity generates substantial revenue for the state treasury, sandstone waste causes many environmental and health-related problems. The dumping sites are a source of many toxic elements that are hazardous to human health (Ahmad, 2014; Singhal and Geol, 2022), and dust deposition reduces crop productivity and deteriorates soil properties (Kumawat *et al.*, 2024).

The reuse potential of stone waste is now an active area of research to reduce the number of onsite dumping (Harshwardhan *et al*., 2017; Kumar *et al*., 2017a; Tunc, 2019; Tunc and Alyamac, 2019); parallel understanding of the natural reclamation process and the time scale required to support vegetation of such dumps is essential for ecological restoration and land reclamation. Studies of soil recovery in a chronosequence have mainly focused on coal mine spoils (Srivastava *et al*., 1989; Pasayat and Patel, 2015; Sena *et al*., 2021; Jeiner and Juan, 2023), probably due to extensive scale and deeper history of extraction. Smart and Singer (2023) compared a series of eleven spoil piles deposited over 30 years and reported an increase in organic matter and a decrease in heavy metal concentrations over time. While soil development on spoils or soil dumping is normally seen as a linear process of accumulating nutrients with time (Zhao *et al*., 2013; Kumar *et al*., 2015), the same is not reflected in vegetation development because of the complexity of the process involving many factors (Prach and Walker, 2020).

Many long-term *in situ* observations on soil development and revegetation have provided a detailed understanding of the natural restoration process in mined spoil dumping (Jha and Singh, 1991; Banerjee *et al*., 2000; Zhao *et al*., 2013; Markowicz *et al*., 2015; Jeiner and Juan, 2023), but small-scale pot experiments to determine the time scale over which these spoils become capable of supporting vegetation using model crops are scant. In the state of Mizoram, stone quarrying sustains the livelihood and economy of the many local people. During 2021-22, the state produced 7,42,862m^3 of stone with over 450 mining permits. The quarries are located in small patches distributed across the state but mainly in the Aizawl district. The main uses of this rock are road construction and, in some cases, local people use it as building materials. Although the current scale of production is comparatively low, evidence of environmental hazards related to the activity has started to emerge (Devi *et al*., 2015)

The present study aimed to focus on understanding how soil properties evolve on sandstone spoils to discern patterns of soil development and identify key changes that occur as the soil matures. In addition, the growth parameters of a model crop species,*Coriandrum sativum* (Coriander), planted in soils from different stages of the chronosequence under greenhouse conditions are evaluated.

MATERIALS AND METHODS

Sampling sites

Quarries around Aizawl City, Mizoram, India, were surveyed and the locations of sandstone spoiler dumping sites were enquired about by the onsite workers and/or local people. The information about the age of the dumped spoils was then noted. The fresh dumping site is located at PTC Road, dumping sites of ages 2, 8, 10 and 12 years are located at Lawipu, and dumping sites of 4 and 6 years are located at Melthum (Fig. 1). The freshly dumped sandstone site was considered as the control because the primary objective of the study was to observe soil property dynamics and its effect on plant growth with increasing age of dumping. From each site, an adequate amount of soil for soil analysis and preparing nursery beds was collected to a depth of 20cm during February 2024.

Soil analysis

One kg soil from each site was brought to the laboratory at Mizoram University, Aizawl, India for soil analysis. A part of the fresh soil samples was used to determine soil properties such as moisture content, pH and electric conductivity within 72 hours of collection and the rest of the soil samples were air dried for a week. The dried soil was then ground to fine powder, and the water holding capacity was estimated. Basic soil nutrient content analyzed were organic carbon, available phosphorus (Bray *et al*., 1945), available nitrogen (Subbiah *et al*.,1956), and available potassium (Black, 1965).

Growth performance of model crop

The top layer of soil collected from dumping sites of different ages was used to prepare beds 30cm in height under a greenhouse at Mizoram University, Aizawl, India. Completely Randomized Block design with 3 replicates for each treatment was used to grow the Surabhi variety of *C. sativum*. One hundred seeds were sown in each replicate at a spacing of 15x15cm during March 2023 in bed size 1.5x1.5m.

Seed germination was observed till 14 days after sowing (DAS), and based on the daily germination count, germination percentage, mean daily germination, peak germination and germination values were calculated following Czabator (1962).

For assessing growth parameters, the height of the shoot was measured at 15, 30, 45 and 60 days from the date of sowing. To carry out the measurements, 15 coriander plants from each replication were tagged, and the height of the shoot was measured in cm from the collar region to the tip of the highest shoot. Root length was measured at 30 and 60 days after sowing.

For assessing the biomass, 5 random samples from each replication were removed at 30DAS and 60DAS. The plants are thoroughly washed for measuring fresh shoot and root weight. The root and shoot were then separated, packed in aluminium foils and dried in hot air oven at 75°C for 48 hours. Thereafter, shoot and root dry weights were measured (Mishra and Solankhe, 2008).

The data obtained for germination, growth and biomass was subjected to statistical analysis as described by

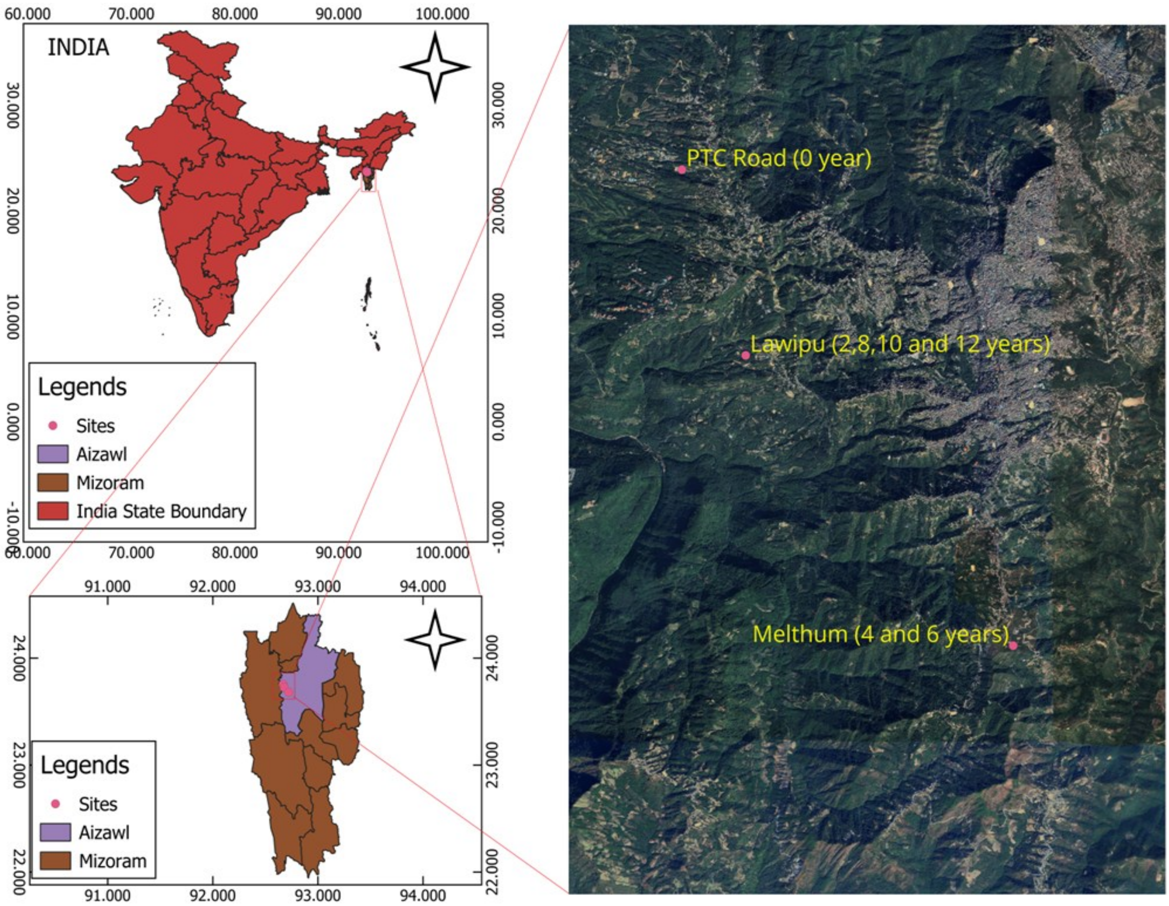

Fig. 1. *Showing the location of dumping sites around Aizawl City, Mizoram*

Panse and Sukhatme (1961) to test the significance. The data was then subjected to a One-way analysis of variance (ANOVA) using CRD design.The mean values were compared with the critical difference (CD) values, which were calculated separately for each parameter at 5 per cent significance level using the Least Significant Difference method.

RESULTS AND DISCUSSION

The physicochemical properties of sandstone wastes dumped near the quarry sites improved with age. Water holding capacity increased to 66.63 % in the 8-year-old dumping site, and the moisture content increased to 25.75%(Table 1). The pH decreased from 7.73in the fresh dump to 5.44 in the 8-year-old dumping, which then increased to 6.69in the 12-year-old dumping. The reduction in the electric conductivity followed a similar trend, dropping from 13.16 dS/m to 3.45 dS/m in the 8-year-old dumping spoil. Significant variation existed across the 7 age categories for water holding capacity, moisture content, pH and electric conductivity. The decrease in electrical conductivity of the soil samples over time could be due to the loss of soluble salts and nutrients from the soil through leaching and plant uptake. The data suggests that soil dumping age influences electrical conductivity. This may be due to factors such as leaching or the negative relationship that soil pH has on electrical conductivity (Aizat *et al*., 2014). Devi *et al*. (2015) observed a similar moisture content value (25.4%) in highly disturbed quarry areas which were currently mined at Sirang in Mizoram. They further reported a decline of pH values in unmined soils, mined 10 years ago, and currently mined. Manpoong and Tripathi (2019) analyzed soils under different land uses in Mizoram and reported pH values ranging from 3.9in natural forests to 4.9 in bamboo forests.

The soil organic carbon ranged from 0.46% in fresh dumping to 0.78% in the 10-year-old dumping. The values reported are low but not so different from those in agricultural soils of Assam, which was between 1.87-3.198% (Nath *et al*., 2014), West Bengal between 0.24 – 0.71% (Dhakad *et al*., 2020), and Madhya Pradesh (0.53%; Patidar *et al*., 2017). Significant differences for available nitrogen and potassium were observed across dumping of various ages (Table 2) but not for phosphorus. Extremely low available nitrogen (38kg/ha) content was reported in a fresh dump, while the highest value was observed in soils of an 8-year-old dumping site(217.33kg/ha). Available potassium was the lowest in the 2-year-old dump (155.44kg/ha) and highest in the 10-year-old dump (252.59kg/ha). Accord-

Table 1. Soil physicochemical properties of sandstone spoils at dumping sites of different ages during 2024

Dumping Age	Water Holding Capacity (%)	Moisture Content (%)	pH	Electrical conductivity (dS/m)
0 years (Fresh)	38.42±1.58	2.10±0.50	7.73±0.19	13.16±0.17
2 Years	44.48±1.40	9.99±0.18	6.72±0.01	12.00±0.29
4 Years	41.85±0.22	9.17±0.24	6.40±0.01	9.17±1.32
6 Years	56.98±2.88	22.96±0.46	5.72±0.11	4.47±0.11
8 Years	66.63±5.74	25.75±0.38	5.44±0.09	3.45±0.23
10 Years	53.21±0.67	10.58±0.27	5.97±0.01	8.19±0.18
12 Years	47.20±0.58	9.98±0.17	6.69±0.06	7.86±0.33
CD@0.05	7.80	1.03	0.28	1.67
CV (%)	8.95	4.51	2.49	11.31

Table 2. Soil nutrients of sandstone spoils at different ages of dumping during 2024

Dumping Age	Organic Carbon (%)	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)
Fresh	0.46±0.06	38.00±0.00	10.28±0.43	156.94±6.85
2 Years	0.49±0.08	171.66±4.33	13.31±1.60	147.97±5.18
4 Years	0.49±0.01	117.00±4.00	14.42±0.74	161.42±5.18
6 Years	0.91±0.03	167.33±4.33	11.26±0.46	171.88±1.49
8 Years	0.72±0.11	217.33±4.33	11.76±1.60	209.25±19.43
10 Years	0.78±0.10	167.33±4.33	10.04±1.27	252.59±6.51
12 Years	0.75±0.02	146.66±4.33	11.14±1.33	155.44±18.73
CD @0.05	0.22	12.13	NS	34.21
CV (%)	18.57	4.69	17.09	10.79

Table 3. Germination attributes of Coriandrum sativum observed 14 days after sowing under greenhouse conditions at Mizoram University, Aizawl.

Dumping age (years)	Germination (%)	Mean daily germination (%)	Peak Value (%)	Germination Value
Fresh	80.21±1.80	5.73±0.13	9.15±1.08	52.68±7.17
2Years	85.07±2.71	6.08±0.19	9.45±0.30	57.55±3.65
4Years	76.39±1.93	5.46±0.14	8.55±0.53	46.69±3.32
6Years	76.39±3.82	5.46±0.27	6.94±0.35	38.08±3.70
8Years	85.42±7.51	6.10±0.54	8.62±0.62	52.68±6.49
10Years	100.00±0.00	7.14±0.00	12.50±0.00	89.29±0.00
12Years	74.31±10.23	5.31±0.73	8.19±1.72	45.93±15.40
CD@0.05	16.00	1.14	2.60	22.20
CV (%)	10.93	10.93	16.16	22.98

ing to the rating chart for soil test data prepared by Tamil Nadu Agricultural, Coimbatore (https://agritech.tnau.ac.in/agriculture/agri_soil_soilratingchart.html), the highest level of nitrogen recorded in the present study falls short of the low category of<240kg/ha. However, The potassium and phosphorus levels were well within the medium category (110-280kg/ha and 11-22kg/ha). The soil nutrient properties of sandstone dumps were similar to land under cultivation in the dry parts of western India (Kumar *et al.,* 2017; Kumar *et al.,* 2017a).

Significant variation for all germination parameters was found among dumps of different ages (Table 3). A hundred per cent germination was recorded in the 10-year-old dump with mean daily germination of 7.14 ± 0.00 and a germination value of 89.29± 0.00. Seeds in the fresh dumps also showed high germination attributes,indicating no negative effect of fresh dumps on seed germination.In many instances, seeds sown on fresh sand spoils in the Great Lake Basins of the United States of America are not adversely affected, but soil amendments have improved germination to a certain extent (Aschenbach *et al*., 2012; Aschenbach and Poling, 2015).

Growth parameters such as plant height and root length began to reveal significant differences after 30 days of sowing. Highest plant height was observed in 12-year-old dumps at 45DAS (10.03cm) and 60DAS (13.73), as shown in Fig.2. Further root length was observed to be highest in soils of 12-year-old dumps (6.02cm) and low-

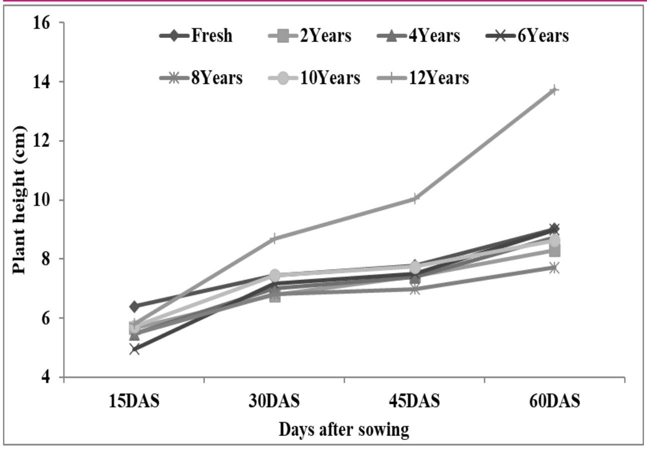

Fig. 2. *Plant height (cm) of Coriandrum sativum taken at 15 days intervals after sowing under greenhouse conditions in Mizoram University, Aizawl*

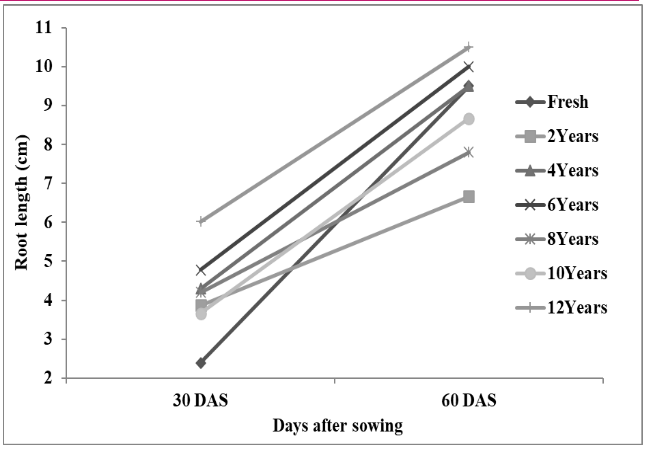

Fig. 3. *Root length (cm) of Coriandrum sativum taken at 30 and 60 days after sowing under greenhouse conditions in Mizoram University, Aizawl*

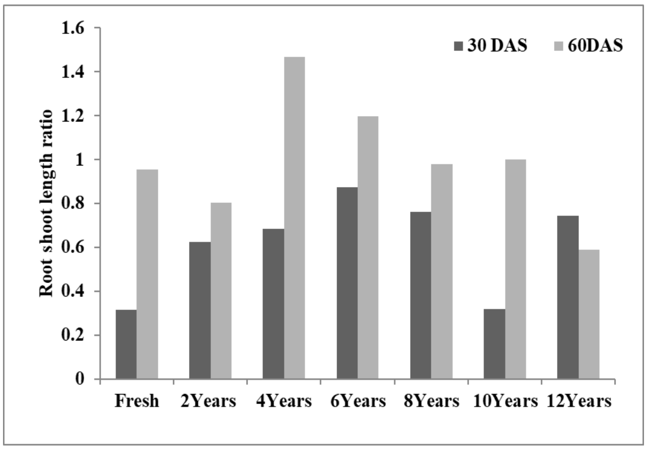

Fig. 4. *Root to shoot length ratio of Coriandrum sativum at 30 and 60 days after sowing under greenhouse conditions in Mizoram University, Aizawl*

est in fresh dumps (2.39cm) measured 30DAS. However, at 60DAS, the average root length of plants in fresh dump increased dramatically with an almost 300% jump (Fig 3). Root: Shoot (R:S) ratio is characteristically linked with resource availability and is one of the mechanisms by which plants cope with limitations imposed by growth-constraining resources in the environment (Mašková and Herben, 2018). In environments with poor nutrition, nutrient allocation was more focused on the root portion (Tilman. 1985). In the study, except at 12 years, the present study observed an increasing root-to-shoot length ratio in all other treatments at 30DAS and 60DAS (Fig 4), probably indicating the onset of stress due to the depleting nutrient status, especially organic carbon and nitrogen, of the soils as plant growth increases.

Regarding biomass, significant variation was found for fresh shoot weight at 30DAS and all measured parameters at 60DAS. Although growth measurements failed to show any constant growth trend with an increase in the age of dumping, for all parameters highest growth values were reported in 12-year-old dumps measured 60DAS (Table 4). This can only indicate that other growth limiting factors may be in play during the initial years of soil build-up, such as the presence of heavy metals, erosion of topsoil, and micronutrient deficiency.Nevertheless, the highest growth values obtained at 12-year-old dumps fall extremely short when compared to coriander plants grown commercially. At 60DAS, Kuri *et al*. (2015) recorded an average plant of 13.84cm grown under loamy sand (80.7% sand, 10.9% silt and

Table 4. Plant biomass (per plant) of *Coriandrum sativum* grown in different quarry spoils at 30DAS and 60 DAS during 2024

Dumping age	30 DAS			60 DAS		
	Fresh root Weight (g)	**Fresh shoot Weight(g)**	**Dry shoot Weight (g)**	**Fresh root Weight (g)**	**Fresh shoot Weight(g)**	**Dry shoot Weight (g)**
Fresh	0.0018±0.00	0.085±0.01	0.0074±0.00	0.069±0.02	0.45±0.07	0.068±0.02
2Years	0.0016±0.00	0.030±0.00	0.0047±0.00	0.010±0.00	0.14±0.01	0.024±0.02
4Years	0.0022±0.00	0.053±0.01	0.0050±0.00	0.045±0.01	0.17±0.07	0.005±0.00
6Years	0.0043±0.00	0.068±0.01	0.0060±0.00	0.050±0.02	0.34±0.10	0.006±0.00
8Years	0.0056±0.00	0.043±0.01	0.0051±0.00	0.067±0.01	0.29±0.08	0.005±0.00
10Years	0.0027±0.00	0.052±0.01	0.0048±0.00	0.042±0.00	0.23±0.09	0.022±0.02
12Years	0.0042±0.00	0.100±0.02	0.013±0.00	0.097±0.01	1.20±0.07	0.418±0.02
CD@0.05	NS	0.04	NS	0.04	0.23	0.04
CV (%)	61.61	36.18	48.23	42.91	32.00	28.45

8.3% clay), alkaline in reaction (pH 8.2) with low organic carbon (0.17%), medium in available phosphorus (14.6 kg/ha) and available potassium (148.6 kg/ha). In a study to evaluate the growth among thirty genotypes of coriander collected from Karnataka and Andra Pradesh, plant height at 60DAS ranged between 49.09cm and 71.81cm (Nagappa *et al*., 2016). The root and shoot fresh weight of coriander plants grown in semi-arid conditions in Rajasthan were 0.35gm and 2.27gm 45DAS (Mishra *et al.,* 2017). This indicates that even after 12 years, the sandstone dump could not support plants' luxuriant growth, reiterating the hazardous impact of dumping on the site and the neighbouring areas.

Conclusion

The study revealed a higher pH and electrical conductivity level in freshly dumped sandstone quarry spoil at PTC Road, which decreased significantly as the soil matured with age. However, except for available phosphorous, soil properties such as water-holding capacity, soil organic carbon, nitrogen, and potassium improved with increasing age. Although germination attributes did not vary in the differently aged spoils, growth parameters of *Coriandrum sativum* improved significantly with the increasing age of the dumping soil, indicating evident nutrient replenishment during natural successional processes that supported plant growth. However, the sluggish growth of the model plant, even after 12 years, suggests that the period is inadequate to fully rejuvenate the soil to support luxuriant plant growth. Such sites warrant supportive soil amendment practices to accelerate restoration and vegetation recovery. Although the study gives preliminary insight into understanding how soil properties evolve on sandstone spoils and its impact on plant growth, a detailed in situ investigation is necessary to affirm the present studied findings.

Conflict of interest

The authors declare that they have no conflict of interest.

REFERENCES

1. Agrawal, K. & Gaharwar, P. S. (2013). A study on trend of export of natural stones from india to various countries. *Int. J. Advan. Res. Technol*, *2*(7), 360-379.
2. Ahmad, A. (2014). A study of miners, demographics and health status in Jodhpur district of Rajasthan, India. *Int J Develop Stud Res*, *3*(1), 113-21.
3. Aizat, A. M., Roslan, M. K., Sulaiman, W. N. A.& Karam, D. S. (2014). The relationship between soil pH and selected soil properties in 48 years logged-over forest. *International Journal of Environmental Sciences*, *4*(6), 1129-1140.
4. Aschenbach, T. A.& Poling, M. (2015). Initial plant growth in sand mine spoil amended with organic materials. *Ecological Restoration*, *33*(2), 197-206. https://doi.org/10.3368/er.33.2.197
5. Aschenbach, T. A., Brandt, E., Buzzard, M., Hargreaves, R., Schmidt, T.& Zwagerman, A. (2012). Initial plant growth in sand mine spoil amended with peat moss and fertilizer under greenhouse conditions: Potential species for use in reclamation. *Ecological restoration*, *30*(1), 50-58. https://doi.org/10.3368/er.30.1.50
6. Banerjee, S., Das, P.& Mishra, T. (2000). Microbial and Nutritional Characteristics of Coal Mine Overburden. *Journal ofthe Indian Society of Soil Science*, *48*(1), 63-66.
7. Black, C.A. (1965). Methods of soilanalysis Part I Am. Soc. Agron. Inc. Publi. Madison Wisconsin USA
8. Bray, R.H. & Kurtz, L.T. (1945). Determination of total, organic, and available forms of phosphorus in soils. *Soil Sci, 59 (1)*, 39–46.
9. Czabator, F. J. (1962). Germination value: an index combining speed and completeness of Pine seed gerrmination. *Forest Science, 8,* 386-396.
10. Devi, G. P., Thasangzuala, Z. R.& Mishra, B. P. (2015). Effect of sandstone quarry on soil characteristics of subtropical forests in Mizoram, North-East India. *Journal of Chemical and Pharmaceutical Research*, *7(3),* 13-19.
11. Dhakad, R., Kumar, P.& Sharma, C. K. (2020). Status of soil pH, EC, OC and micronutrients levels in Madhya Pradesh: An overview. *Journal of Pharmacognosy and Phytochemistry*, *9*(5S), 04-09.
12. Harshwardhan, S. C., Kalla, P., Nagar, R. & Gautam, P. K. (2017). Partial Replacement of Cement by Kota Stone Slurry in Mortar. *STM Journals*, *7*(3), 8-13.
13. Indian Minerals Yearbook 2020 (Part- III : Mineral Reviews) 59th Edition 30.21 Slate, Sandstone & Other Dimension Stones, Government Of India Ministry Of Mines Indian Bureau Of Mines
14. Jha, A. K. & Singh, J. S. (1991). Spoil characteristics and vegetation development of an age series of mine spoils in a dry tropical environment. *Vegetatio*, *97*, 63-76. https://doi.org/10.1007/BF00033902
15. Jeiner, C. B. & Juan, L. P. (2023). Soil recovery in a chronosequence of revegetated coal mine spoils in Colombian drylands: a view from the assessment of physical-chemical and biological properties. *Geoderma Regional, 33,* 1-9. e00652. 10.1016/j.geodrs.2023.e00652. https://doi.org/10.1016/j.geodrs.2023.e00652.
16. Kumar, D., Yadav, S. R., Kaur, R., Choudhary, A. & Meena, B. S. (2017). Soil fertility status and nutrient recommendations based on soil analysis of Jaisalmer district of western Rajasthan. *Asian Journal of Soil Science*, *12* (1), 103-07.DOI: 10.15740/HAS/AJSS/ 12.1/103-107.
17. Kumar, M., Yadav, S. R. & Gulati, I. J. (2017)a. Evaluation of soil status in Sriganganagar district of Rajasthan. *International Journal of Chemical Studies*, *5*(4), 776 -780.
18. Kumar, S., Maiti, S. K., & Chaudhuri, S. (2015). Soil development in 2–21 years old coalmine reclaimed spoil with trees: A case study from Sonepur-Bazari opencast project, Raniganj Coalfield, India. *Ecological engineering*, *84*, 311-324.https://doi.org/10.1016/j.ecoleng.2015.09.043.
19. Kumawat, A., Rashmi, I., Kala, S., Jat, R., Sharma, G. K.,

Meena, G. L. & Yadav, D. (2024). Impact of Stone Mining on the Agricultural Sectors and Suggestive Rehabilitation Measures. In *Ecological Impacts of Stone Mining: Assessment and Restoration of Soil, Water, Air and Flora* (pp. 113-133). Singapore: Springer Nature Singapore.https://doi.org/10.1007/978-981-97-4746-7_7

20. Kuri, B R., Jat, N., Shivran, A., Saharawat., Yashpal Bana, R S. &Dadarwal, R. (2015). Effect of sowing time, varieties and plant growth regulators on growth, physiological indices and productivity of coriander (Coriandrum sativum) Corresponding. Indian Journal of Agronomy. 60. 464-470. https://doi.org/10.59797/ija.v60i3.4481
21. Manpoong, C. & Tripathi, S. K. (2019). Soil properties under different land use systems of Mizoram, North East India. *Journal of Applied and Natural Science*, *11*(1), 121-125. https://doi.org/10.31018/jans.v11i1.1999
22. Markowicz, A., Woźniak, G., Borymski, S., Piotrowska-Seget, Z. & Chmura, D. (2015). Links in the functional diversity between soil microorganisms and plant communities during natural succession in coal mine spoil heaps. *Ecological Research*, *30*, 1005-1014.https://doi.org/10.1007/s11284-015-1301-3
23. Mašková, T. &Herben, T. (2018). Root: shoot ratio in developing seedlings: How seedlings change their allocation in response to seed mass and ambient nutrient supply. *Ecology and Evolution*, *8*(14), 7143-7150. https://doi.org/10.1002/ece3.4238
24. Mishra, A. & Salokhe, V. M. (2008). Seedling characteristics and the early growth of transplanted rice under different water regimes. *Expl Agric., 44,* 1-9. doi:10.1017/S0014479708006388
25. Mishra, B. K., Dubey, P. N., Aishwath, O. P., Kant, K. R. I. S. H. N. A., Sharma, Y. K. & Vishal, M. K. (2017). Effect of plant growth promoting rhizobacteria on coriander (Coriandrum sativum) growth and yield under semi-arid condition of India. *Indian J. Agric. Sci*, *87*(5), 607-612. https://doi.org/10.56093/ijas.v87i5.70124
26. Nagappa, M. K., Dorajeerao, A. V. D. & Reddy, M. L. (2016). Qualitative and yield characters in coriander genotypes. *Plant Archives*, 16, (2), 1005-1010
27. Nath, T. N. (2014). Soil bulk density and its impact on soil texture, organic matter content and available macronutrients of tea cultivated soil in Dibrugarh district of Assam, India. *International Journal of Development Research*, *4* (2), 343-346.
28. Panse, V.G. &Sukhatme, P.V. (1985). Statistical methods for agricultural workers. Fourth edition. The Indian Council of Agricultural Research, **N**ew Delhi, India. p. 1-381.
29. Pasayat, M. & Patel, A. K. (2015). Assessment of physicochemical properties influencing mine spoil genesis in chronosequence iron mine overburden spoil and implications of soil quality. *International Journal of Current Microbiology and Applied Sciences*, *4*(6), 1095-1110.
30. Patidar, N. K., Patidar, R. K., Rajput, A., Sharma, S. K. & Thakur, R. (2017). Evaluation of basic properties of soil and major nutrient in soils of Jhabua district of Madhya Pradesh. *International Journal of Agriculture, Environment and Biotechnology*, *10*(1), 45-52. DOI : 10.5958/2230-732X.2017.00008.0
31. Prach, K. & Walker, L. R. (2020). Comparative plant succession among terrestrial biomes of the world. Cambridge University Press.
32. Sena, K. L., Yeager, K. M., Barton, C. D., Lhotka, J. M., Bond, W. E. & Schindler, K. J. (2021). Development of mine soils in a chronosequence of forestry-reclaimed sites in eastern Kentucky. *Minerals*, *11*(4), 422.https://doi.org/10.3390/min11040422
33. Singhal, A. & Goel, S. (2022). Impact of Sandstone Quarrying on the Health of Quarry Workers and local residents: a case study of Keru, Jodhpur, India. In: *Treatment and disposal of solid and hazardous wastes* (pp. 97-118). Cham: Springer International Publishing. https://doi.org/10.1007/978-3-030-29643-8_5
34. Smart, K. E. & Singer, D. M. (2023). Surface Coal Mine Soils: Evidence for Chronosequence Development. *Soil Systems,* 7(2), 59.https://doi.org/10.3390/soilsystems7020059
35. Srivastava, S. C., Jha, A. K.& Singh, J. S. (1989). Changes with time in soil biomass C, N and P of mine spoils in a dry tropical environment. *Canadian Journal of Soil Science*, *69*(4), 849-855. https://doi.org/10.4141/cjss89-085
36. Subbiah, B.V. & Asija, G. L. (1956). A rapid procedure for the estimation of nitrogen in soils. Curr. Sci., 25, 259-260.
37. Tilman, D. (1985). The resource-ratio hypothesis of plant succession. *American Naturalist, 125, 827–852*. https://doi.org/10.1086/284382
38. Tunc, E. T. (2019). Recycling of marble waste: A review based on strength of concrete containing marble waste. *Journal of environmental management*, *231*, 86-97. https://doi.org/10.1016/j. jenvman.2018.10.034.
39. Tunc, E. T.& Alyamac, K. E. (2019). A preliminary estimation method of Los Angeles abrasion value of concrete aggregates. *Construction and Building Materials*, *222*, 437-446. https://doi.org/10.1016/j.conbuildmat.2019.06.176.
40. Zhao, Z., Shahrour, I., Bai, Z., Fan, W., Feng, L. & Li, H. (2013). Soils development in opencast coal mine spoils reclaimed for 1–13 years in the West-Northern Loess Plateau of China. *European Journal of Soil Biology*, *55*, 40-46.https://doi.org/10.1016/j.ejsobi.2012.08.006