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# Dust-Holding Capacity and Bio-Chemical Changes of Plant Species Growing in an Around Opencast Mining Area of Bundelkhand Region of Uttar Pradesh, India

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## Abstract

The present study has been carried out on a total of 50 available plant species to assess their dust-capturing capacity and biochemical performances in and around open cast granite mine areas of Jhansi district and Bundelkhand University campus treated as control site. Plant species existing under a polluted environment for a long time may be considered as potentially resistant species and recommended for green belt design in mining areas, especially to cope with dust pollution. Results showed the pollution level, especially of mining-originated dust particles holding capacity of leaves and effects of different biochemical parameters (Total Chlorophyll, Protein and Carotenoid) of existing plant species both from mining areas as well as from Bundelkhand University campus. Based on their performances, *Tectona grandis* L., *Ficus hispida* L., *Calotropis procera* Aiton., *Butea monosperma* Lam. and *Ficus benghalensis* L., etc. are highly tolerant species while *Ficus infectoria* L., *Artocarpus heterophyllus* Lam., *Ipomoea purpurea* L., *Allianthus excelsa* Roxb. and *Bauhinia variegata* L. are intermediate tolerant species. *T. grandis* had shown the highest dust-holding capacity (2.566 ± 0.0004 mg/cm$^2$) whereas *Albizia procera* (0.018 ± 0.0002 mg/cm$^2$) was found to be the lowest dust-holding capacity. Our findings also showed that the *T. grandis* and *F. hispida* have significant dust deposition with minimal effect of dust on their leaf chlorophyll (17.447 ± 0.019 mg/g and 14.703 ± 0.201 mg/g), protein (0.699 ± 0.001 mg/g and 0.604 ± 0.002 mg/g) and carotenoid (0.372 ± 0.003 mg/g and 0.354 ± 0.003 mg/g) content respectively among all selected plant species. Therefore, in the present investigation, plant species with high tolerance to high dust-holding capacity on their leaf surfaces are preferable for green corridors as open cast granite mines and their adjacent areas.

**Keywords**

Bundelkhand Region, Biochemical Changes, Dust-Holding Capacity, Chlorophyll Content, Open Cast Granite Mining

## 1. Introduction

In the developing countries, especially India, the stone crushing industry plays an important role, which produces raw materials for various construction activities such as bridge, building, canal, highway road and railway track, etc. on the basis of the requirement. There are more than 12,000 stone crusher units in India, but keeping in mind the rapid urbanization and industrialization, this number is expected to more than double in the next decade. In India, the stone-crushing industry represents a financially significant sector because its annual turnover is more than Rs. 5000 million (more than 1 billion US dollars). It is estimated to provide direct employment to more than 500,000 people engaged in various activities like mining, crushing plants, transportation of mining stones and crushing products, etc. Most of the workers of stone crushers are related to rural and economically backward areas because there are limited employment opportunities. Stone crusher is an industry that is present in and around almost all major cities/towns of the country because construction activities run throughout the year. Since the cost of crushed stone products increases with the transportation of stones over long distances, therefore crushers need to be located near demand centers, like cities, bridges, canals, etc. Stone crushers also require electricity and a lot of manpower for their operation.

Crushers are always located near the source of raw materials such as stone mines, river beds, etc. Although stone crusher industries are a socio-economically backward area, this leads to a large amount of dust emissions, which causes respiratory diseases and creates health hazards for the surrounding population, along with the workers. Dust also adversely affects visibility, reduces the growth of vegetation and affects the aesthetics of the region.

In order to prevent/control these emissions, Central Pollution Control Board (CPCB) has already developed emission standards and guidelines in 1989, which were notified by the Ministry of Environment and Forests (MoEF) under the Environmental Protection Act (EPA) (1986), based on technical-economic viability for achieving standards.

In country like India, air pollution is an unavoidable harmful by-product of rapid industrialization and urbanization that is responsible for a variety of deleterious effects on both human and plant communities [1]. It has been a major environmental concern since the beginning of industrialization, resulting in a release of gaseous and particulate pollutants into the atmosphere. Industrialization has provided humanity with materials and social benefits. It has also brought in its wake up many unwanted substances and social problems. One of

these problems is the degradation of our surrounding environment. Worldwide mining activity is one of the serious contributors to the environmental pollution and is considered one of the significant sources of air, soil and water pollution [2]-[4]. Pollutants released mix with the atmosphere and are transported at a long distance through the air from the mining area and leading to pollution in the surrounding undisturbed area [5]. The extraction of valuable minerals from an ore body, known as quarrying, often results in the degradation of ambient air quality due to the emission of dust particles in the range of 0 to 75 μm [6]. Vehicular movements, windstorms blowing over processed stockpiles, overburden, mine ore, and aggregate in transit contribute significantly to the degradation of ambient air quality in the mining areas [7]. The rapid growth of our global population and an associated increase in economic development are placing an ever-increasing stress on the availability of natural resources. Increased production has also resulted in a considerable amount of waste that has adverse effects on the surrounding flora, fauna as well as human beings. A key component associated with infrastructure development is the use of crushed rock (e.g. for road and building construction). During crushing and screening operations, the resulting dust is a primary air pollutant that can have a considerable effect on surrounding flora and fauna. The effects include a change in soil productivity and pH, decreased visibility in the neighboring areas, increased number of people with chronic respiratory illnesses and allergies, and degradation of natural habitats and resources, such as economic crops [8]-[11]. When the weather is dry, nations like India produce a lot of dust from their soil [12]. Dust deposition on plants increases due to activities viz., open-cast mining, loading and unloading of crushing stone, road traffic, poorly maintained roads, agriculture-related activities, construction and demolition activities, brick kilns industries and other industrial activities [13]. The dust deposited onto the foliar surfaces affects their morphological features as well as biochemical constituents [14] [15]. Air pollutants can negatively affect the biochemistry and physiology of plants, leading to a reduction in overall growth and development: These effects have been studied for many years [16]-[19]. As air currents flow through a tree canopy, some dust particles stick to the leaves, while others are deflected and deposited elsewhere. The fate of the particles depends on their size and other physical and chemical properties, wind speed, and the surface topography of the deposition zones. After deposition, the dust particles may remain on leaf surfaces until it rains or the leaf abscises and decomposes [20] [21]. Several factors contribute to the dust retention capacity of vegetation, including canopy structure, foliage density and morphology (roughness, leaf convection, presence of trichomes), and ambient meteorological conditions [21]-[25]. Dust accumulation affects plant physiological parameters by reducing photosynthetic rate and characteristics can also influence dust levels and thus leaf characteristics [26] [27]. Air pollution can damage canopy structure, reduce plant height and plant biomass, and have measurable effects on the internal biochemistry of affected plants. In addition to leaf

surface characteristics, canopy morphology, structural configuration, leaf density, leaf inclination, and other factors that influence vegetation resistance to PM, a number of environmental factors such as precipitation, strong winds, dust storms, and human factors such as traffic flow and heating influence the effects of pollution/dust in the air [28] [29]. Fine dust increases leaf temperature up to 10 times more than coarse dust. Even at very low concentrations, fine dust particles can affect leaf function, while higher densities of coarse particles are required to have corresponding effects [30]. The features of the trees, like the canopy cover, leaf size, hardness, texture, etc., enhance the capacity of trees in lowering the pollutant level in the atmosphere [31]. Trees with large canopy cover restrict the pollutant's downwind movements, and they also filter the air, which enhances environment quality [32]. Studies found that the vegetation to be used cannot be generalized and needs to be appropriately studied before its implementation, as, in open road conditions, tall trees had a more significant impact [33]. The process of green belt development requires proper management of plants and their growth. Then better management can be acquired by using naturally occurring and eco-friendly products. The air pollutants can also damage vegetation, by causing morphological changes, blocking the leaf pores making them less productive, and causing genetic modifications to the plants like stunt growths [34]. The tree species with maximum air pollutants and dust particles absorbing capacity with minimal impact on themselves can be chosen for plantation [27] [35]. The tolerance capacity of tree species can be well known depending on specific four biochemical and physiological parameters [36]. Plants help in combating the problem of air pollution, but in this process, they also get affected because of their continuous exposure to a particular environment. In the polluted environment, changes in plant morphological, physiological, and biochemical parameters (chlorophyll, carotenoid, and protein content) can be observed. Chlorophyll measurement has an imperative part in metabolism, and reduced chlorophyll concentration links directly with development of plants [37]. In addition, the severe effects may alter the biochemical and morphological characteristics of an exposed organism, resulting in the initiation of adaptive mechanisms to cope with the altered environment [38]. Several factors contribute to the dust retention capacity of vegetation, including canopy structure, foliage, density and morphology (roughness, leaf convection, presence of trichomes), and ambient meteorological conditions [21]-[25]. Serious environmental problems regarding quarry mining have been mainly observed under open-cast mining, which is common for the extraction of rock aggregate. The tones of overburden material that require extraction to reach the ore body contribute heavily to air quality degradation. The prevention and control of respirable dust have become a major focus of mine dust prevention in many countries, particularly respirable dust with a particle size of less than 5 μm. The reason why respirable dust is difficult to control is that most respirable dust is hydrophobic, which brings great difficulty to dust removal methods [39]. In this context, plants play an

important role in monitoring and maintaining the ecological balance by actively participating in the recycling of nutrients and gases like carbon dioxide and oxygen and also provide a vast area for impingement, absorption, and accumulation of air pollutants to reduce the pollution level in the atmosphere [40].

In the present study, we analyzed the specific physiological and biochemical responses of existing plant species in and around open cast mines towards air pollutants, which might be utilized to recognize those trees with high adaptability and mitigation capacity and purpose for greening around open cast mining areas. It includes fifty native tree species commonly found in the region of Bundelkhand of Uttar Pradesh in India. The species with high pollution tolerating capacity can be recommended for an effective greenbelt development along the roadside. The pollution-tolerant species can also be implemented in other regions with the similar climatic conditions. Generally, plants' respond to dust accumulation varies among species, as deposition varies with foliage orientation, topography, phyllotaxy, epidermal and cuticular characteristics, presence of trichomes, canopy height, and architecture [26] [41] [42]. Plants are involved in biogeochemical cycles and play an important role in monitoring and maintaining ecological balance [43].

## 2. Materials and Methods

### 2.1. Details of the Study Area

The Bundelkhand region of Uttar Pradesh comprises of 7 districts of Jhansi and Chitrakoot Dham divisions and are Jhansi, Lalitpur, Jalaun, Hamirpur, Mahoba, Banda and Chitrakoot (**Figure 1**). Bundelkhand agro-climatic zone of Uttar Pradesh is located in SW corner of U.P. extended between 24˚11'N to 26˚27'N latitudes and 78˚17'E to 81˚34'E longitudes with an average altitude ranging 250 - 300 in above MSL. The Bundelkhand plateau has a gently undulating surface broken occasionally by low, flat-topped hills, which form the specific topographical feature of the region. A number of lower Vindhyan hill ranges are seen in the south and southeast and central portions of Bundelkhand with a maximum height of 2000 feet. The general slope of the region is north to east in southern part, apart from the regular hill range and small rock outcrops on hillocks. In northern part, some small rock outcrops here and there and high ravines along the river banks are characteristics of this region. The landscape of the Bundelkhand region is rugged, featuring undulating terrain with low to medium-level rocky outcrops, narrow valleys and plains. Climatically this region falls under a semi-arid climate, with two main seasons: Monsoon and Dry. The monsoon brings over 90% of the annual rainfall between the months of June to September. Peak summer (May-June) brings excessively high temperature often topping 40˚C, as the hot, dry loo winds sweep in from the desert.

### 2.2. Selection of Study Sites

Present investigation has been carried out on two opencast mining areas of Jhansi

district nament Karari Granite Mine 8 km from Jhansi on national highway NH-75 known as Jhansi-Gwalior highway and another one is Saroj Granite in Jhansi near the village known as Laxmanpura. This site is located on national highway NH-39 known as Jhansi-Khajuraho highway. Bundelkhand University, Jhansi campus has been selected as controlled site.

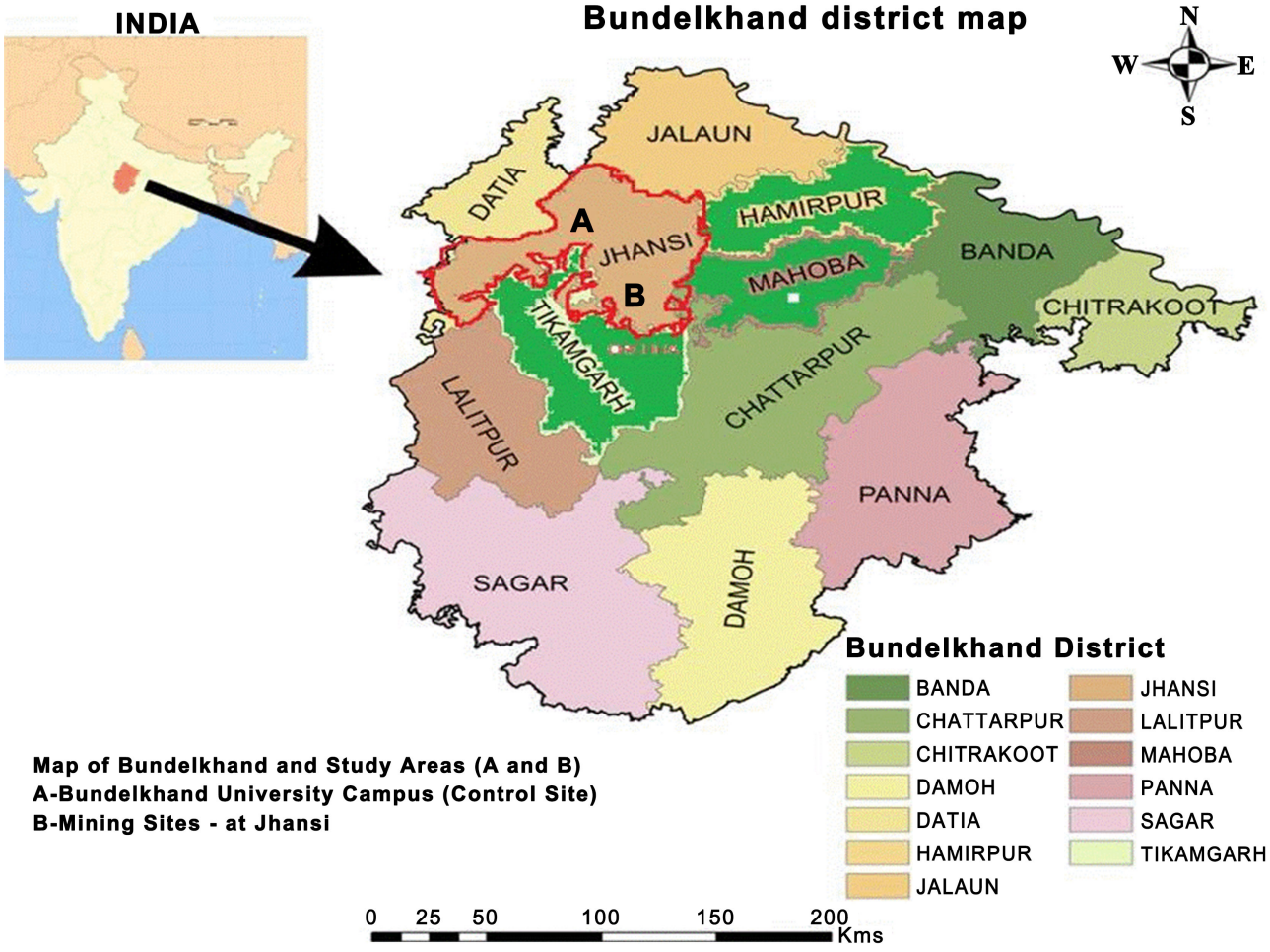


**Figure 1.** Districts of Bundelkhand region as well as study sites as "A" and "B".

## 2.3. Collection of Plant Samples

For present investigation, there are 50 existing plant species which we have been selected from both sites, *i.e.* Jhansi-Khajuraho highway and Jhansi-Gwalior highway nearby mining areas. Leaf sample of 50 different plant species with three replicates of each species have been collected for the measurement of dust deposited on the leaf surface, and analysis of bio-chemical content like Chlorophyll, Carotenoid, Protein. The 50 plant species which have been collected from experimental sites as well as same plant species from BU campus as control site. Fresh leaf samples were wash thoroughly first in tap water followed by distilled water in the laboratory, kept to dry in room temperature (18 degree Celsius) and analyzed for the determination of chlorophylls, carotenoids, protein content, leaf area

and dust measurement.

### 2.4. Measurement of Dust Content

The methodologies have been followed for collection and measurement of dust load. From each plant fully mature leaf samples from different heights were collected randomly than the dust carrying capacity was quantified with the help of a Petri dish. A Petri dish was oven dried, and the initial weight (W1) was weighed. The upper and lower surface dust of a leaf was washed with deionized water and transferred to the Petri dish. Then the Petri dish was completely dried and weighed to record the final weight (W2).

### 2.5. Leaf Area

The leaf area ($cm^2$) has been recorded in triplicate of all existing species in mining areas as well as Bundelkhand University campus (as control site) on the spots with the help of leaf area meter (BIONICS).

### 2.6. Analytical Procedures

Accurately weighted 0.5 g of fresh plant leaf sample have been taken, and homogenized in tissue homogenizer with 10 ml of different extractant solvent. Homogenized sample mixture was centrifuge for 10,000 rpm for 15 min at 4-degree Celsius. The supernatant was separated and 0.5 ml of it is mixed with 4.5 ml of the respective solvent. The solution mixture was analyzed for, total chlorophyll, protein and carotenoids content in spectrophotometer (Perkin). The standard equations used for the quantification of total chlorophyll, protein and carotenoids by different extractant solvents and spectral absorbance for total chlorophyll, protein as well as carotenoids.

## 3. Results and Discussions

Plants are having great role in the defense against to cope with air pollution and other adverse conditions of atmosphere. Dust, aerosols, and other airborne particles are scavenged by plant leaves. Leaf microstructure is characterized by groove area and trichomes which are significantly influenced dust deposition comparing to leaves with the smooth structure; foliar surface morphology has direct effects on the dust capture by leaves which is consistent with a degree of leaf roughness and the number of trichomes in the upper and lower epidermis of a leaf determined the dust retention capacity [44]. Generally, the load of pollution depends on the levels of emission sources, and micrometeorological factors. Plants exposed to pollution experience numerous morphological, physiological, biochemical and ultrastructural changes upon prolonged exposure [45] [46]. Leaves are most sensitive to air pollution as compared to other parts of plants [30] [47]. Dust deposition on the foliage of various plant species is affected by weather conditions, wind direction and plant leaves structures in addition to the sources of environmental contaminants [48]. In present investigation, there are 50 plant spe-

cies have been selected from open cast mining sites as well from Bundelkhand university campus (as control). It has been observed that in present study on the basis of dust-holding capacity out of 50 species the following 10 species have been found maximum deposition of dust. Among these *Tectona grandis* (2.566 mg/cm$^2$) having highest deposition of dust followed by *Ficus hispida* (2.39 mg/cm$^2$), *Calotropis procera* (1.78 mg/cm$^2$), *Butea monosperma* (0.964 mg/cm$^2$), *Ficus benghalensis* (0.924 mg/cm$^2$), *Ficus infectoria* (0.521 mg/cm$^2$), *Artocarpus heterophyllus* (0.345 mg/cm$^2$), *Ipomoea purpurea* (0.294 mg/cm$^2$), *Allianthus excelsa* (0.224 mg/cm$^2$) and *Pongamia pinnata* (0.188 mg/cm$^2$) respectively. Lowest dust deposition has been observed in *Pithecellobium dulce* (0.016 mg/cm$^2$). The variation of dust loading capacity of plant species from mining sites as well as well control site is depicted in Table 1. Study indicated that the tolerance of plant species

Table 1. Dust deposition on leaves of polluted and controlled sites.

| S. No. | Plant Species | Weight of Dust (mg/cm$^2$) Polluted Areas | Weight of Dust (mg/cm$^2$) Unpolluted Areas |
|---|---|---|---|
| 1. | *Adenostoma lavenia* | 0.067 ± 0.00024 | 0.017 ± 0.00018 |
| 2. | *Aegle marmelos* | 0.11 ± 0.00022 | 0.028 ± 0.000153 |
| 3. | *Albizia procera* | 0.018 ± 0.0002 | 0.005 ± 0.000173 |
| 4. | *Allianthus excelsa* | 0.224 ± 0.00027 | 0.123 ± 0.00022 |
| 5. | *Argemone mexicana* | 0.121 ± 0.00026 | 0.031 ± 0.000203 |
| 6. | *Artocarpus heterophyllus* | 0.345 ± 0.00026 | 0.087 ± 0.000203 |
| 7. | *Azadirachta indica* | 0.132 ± 0.00038 | 0.033 ± 0.000289 |
| 8. | *Bambusa vulgaris* | 0.083 ± 0.0002 | 0.021 ± 0.000145 |
| 9. | *Bauhinia variegata* | 0.186 ± 0.00015 | 0.047 ± 0.0001 |
| 10. | *Butea monosperma* | 0.964 ± 0.00026 | 0.241 ± 0.000208 |
| 11. | *Callistemon accuminatus* | 0.02 ± 0.00026 | 0.005 ± 0.000173 |
| 12. | *Calotropis procera* | 1.78 ± 0.00101 | 0.445 ± 0.000751 |
| 13. | *Carissa carandas* | 0.054 ± 0.0002 | 0.014 ± 0.000145 |
| 14. | *Cassia fistula* | 0.088 ± 0.00038 | 0.022 ± 0.000291 |
| 15. | *Causonis trifolia* | 0.149 ± 0.00015 | 0.038 ± 0.000195 |
| 16. | *Chrysophyllum oliviforme* | 0.173 ± 0.00015 | 0.044 ± 0.000115 |
| 17. | *Citrus limon* | 0.131 ± 0.00017 | 0.033 ± 0.000145 |
| 18. | *Cordia dichotoma* | 0.087 ± 0.00017 | 0.022 ± 0.000115 |
| 19. | *Dalbergia sisoo* | 0.023 ± 0.00015 | 0.006 ± 0.000154 |
| 20. | *Datura metel* | 0.156 ± 0.00032 | 0.039 ± 0.000233 |
| 21. | *Eucalyptus globulus* | 0.032 ± 0.00018 | 0.008 ± 0.00012 |
| 22. | *Ficus benghalensis* | 0.924 ± 0.00035 | 0.231 ± 0.000265 |
| 23. | *Ficus hispida* | 2.39 ± 0.00043 | 0.642 ± 0.000346 |
| 24. | *Ficus infectoria* | 0.521 ± 0.00038 | 0.131 ± 0.000265 |

**Continued**

| | | | |
|---|---|---|---|
| 25. | *Ficus religiosa* | 0.12 ± 0.00029 | 0.03 ± 0.000233 |
| 26. | *Gnaphalium polycaulon* | 0.032 ± 0.0002 | 0.008 ± 0.000145 |
| 27. | *Holoptelea integrifolia* | 0.172 ± 0.00032 | 0.043 ± 0.000231 |
| 28. | *Ipomoea purpurea* | 0.294 ± 0.0002 | 0.074 ± 0.000145 |
| 29. | *Jatropha curcas* | 0.183 ± 0.00032 | 0.046 ± 0.000231 |
| 30. | *Kalimeris indica* | 0.028 ± 0.00023 | 0.007 ± 0.00017 |
| 31. | *Lantana camera* | 0.123 ± 0.00026 | 0.031 ± 0.000176 |
| 32. | *Leucaena leucocephala* | 0.098 ± 0.00026 | 0.025 ± 0.000203 |
| 33. | *Lysimachia foemina* | 0.044 ± 0.00018 | 0.011 ± 0.00015 |
| 34. | *Madhuca indica* | 0.099 ± 0.00021 | 0.025 ± 0.000145 |
| 35. | *Mangifera indica* | 0.151 ± 0.00017 | 0.038 ± 0.000145 |
| 36. | *Millettia pinnata* | 0.125 ± 0.00026 | 0.032 ± 0.000173 |
| 37. | *Mitragyna speciosa* | 0.114 ± 0.00019 | 0.029 ± 0.00012 |
| 38. | *Moringa oleifera* | 0.046 ± 0.00018 | 0.012 ± 0.000145 |
| 39. | *Nerium oleander* | 0.04 ± 0.00026 | 0.01 ± 0.000176 |
| 40. | *Phoenix dactylifera* | 0.143 ± 0.00027 | 0.036 ± 0.000208 |
| 41. | *Phyllanthus emblica* | 0.157 ± 0.00015 | 0.04 ± 0.000214 |
| 42. | *Pithecellobium dulce* | 0.016 ± 0.01764 | 0.004 ± 0.013229 |
| 43. | *Polyalthia longifolia* | 0.033 ± 0.00026 | 0.009 ± 0.000173 |
| 44. | *Pongamia pinnata* | 0.188 ± 0.00173 | 0.047 ± 0.001299 |
| 45. | *Psidium guajava* | 0.112 ± 0.00032 | 0.028 ± 0.000231 |
| 46. | *Solanum nigrum* | 0.11 ± 0.00023 | 0.025 ± 0.00017 |
| 47. | *Syzygium cumini* | 0.063 ± 0.00019 | 0.016 ± 0.000153 |
| 48. | *Tectona grandis* | 2.566 ± 0.00026 | 0.598 ± 0.0002 |
| 49. | *Vachellia nilotica* | 0.072 ± 0.00018 | 0.018 ± 0.000145 |
| 50. | *Ziziphus mauritiana* | 0.105 ± 0.00208 | 0.027 ± 0.001545 |

is relatively to the levels of pollution which gives variation from one species to another species and ability to resist pollutants in the existing environment without showing external damage or loss. Contrary to control site, dust load is considered to be an important factor responsible for the decline in leaf performance at the contaminated site [26]. Reductions in the leaf area might be attributed to decreased leaf production, and/or higher rates of senescence caused by the impact of cement dust pollution stress on the photosynthesis capacity and cell elongation mechanism [49] [50]. When exposed to airborne pollutants, most plants experienced physiological changes before exhibiting visible damage to leaves [37]. The use of vegetation samples as bio-indicators of the degree of pollution through biochemical study in environmental monitoring is well established by several studies.

### 3.1. Chlorophyll Content

The photosynthetic pigment Chlorophyll of green plants could be an index of productivity may act as photoreceptor. Chlorophyll plays an important role in plant photosynthesis; hence measurement of total chlorophyll content is a significant measure to assess the effect of pollution on existing plant species in and around mining areas. Chlorophyll measurement under stressful environments is considered to be an imperative tool to assess the effects on plants because of its direct involvement in several metabolic processes. The decreasing levels of the total chlorophyll content of all species have been noticed in the selected plant species in mining areas as compared to control area, *i.e.* Bundelkhand University campus (**Table 2**). Particles of dust physically obstruct sunlight as well as block stomatal pore of leaf and thus dust deposition hinder photosynthetic activities of the plant. Effect of dust reduces leaf pigment concentration which has been reported earlier. In present study maximum chlorophyll content has been observed in leaf of *T. grandis* in unpolluted site (23.044 $mg{\cdot}g^{-1}$) and in polluted site (17.447 $mg{\cdot}g^{-1}$); it was followed by *F. hispida* (19.516 $mg{\cdot}g^{-1}$ and 14.703 $mg{\cdot}g^{-1}$), *C. procera* (26.212 $mg{\cdot}g^{-1}$ and 13.394 $mg{\cdot}g^{-1}$), *F. benghalensis* (16.65 $mg{\cdot}g^{-1}$ and 8.604 $mg{\cdot}g^{-1}$), *D. metel* (14.647 $mg{\cdot}g^{-1}$ and 7.905 $mg{\cdot}g^{-1}$), *M. indica* (14.074 $mg{\cdot}g^{-1}$ and 7.610 $mg{\cdot}g^{-1}$), *B. monosperma* (14.223 $mg{\cdot}g^{-1}$ and 7.491 $mg{\cdot}g^{-1}$), *M. pinnata* (15.985 $mg{\cdot}g^{-1}$ and 7.170 $mg{\cdot}g^{-1}$), *Artocarpus heterophyllus* (14.132 $mg{\cdot}g^{-1}$ and 7.151 $mg{\cdot}g^{-1}$), *Allianthus excelsa* (12.188 $mg{\cdot}g^{-1}$ and 6.891 $mg{\cdot}g^{-1}$) respectively. Lowest chlorophyll content has been found in *Bambusa vulgaris* (4.119 $mg{\cdot}g^{-1}$ in unpolluted area and 2.123 $mg{\cdot}g^{-1}$ in mining area). Due to the adherence of dust on the leaf surface hindering the pathway of light and interfering in the process of chlorophyll formation [51]. Less in total chlorophyll content of plant species depends on the degree of pollution, *i.e.* in present case particulate matter originated from stone crashing units. It has been reported that particulate matter smaller than 1 um in general behave like gas molecules and could therefore penetrate down to the alveoli and can translocate further into the cell tissue and circulation system [52] [53]. Degradation of photosynthetic pigments also indicates the air pollution level. Loss in total chlorophyll content of plant depends on the degree of pollution. Degradation of photosynthetic pigment indicates air pollution [54]. Any reduction in chlorophyll content has direct effect on growth, productivity and tolerance [55]-[57]. It is well documented that plants thriving in polluted environments often display alarming levels of photosynthetic pigments like chlorophyll "a", chlorophyll "b" and total chlorophyll [58]. Pollution-induced photosynthetic pigment degradation was also documented in some studies [57] [59] [60]. Leaf surface crust formation of an alkaline nature is also deliberated to be one of the chief factors that contributed to the reduction in photosynthetic capacity under polluted environments [61]. Plant species produce this organic substance through several important processes like photosynthesis and during respiratory breakdown. Similar reports of chlorophyll degradation and decreased $CO_2$ fixation, and increased respiration, due to cement dust was also reported by Tripathi and Gautam [62].

Table 2. Chlorophyll content (mg/g FW) of plant leaves from polluted and controlled areas.

| S. No. | Plant Species | Polluted | Unpolluted |
|---|---|---|---|
| 1. | *Adenostoma lavenia* | 4.971 ± 0.01817 | 7.825 ± 0.00321 |
| 2. | *Aegle marmelos* | 3.456 ± 0.00952 | 6.521 ± 0.00404 |
| 3. | *Albizia procera* | 6.755 ± 0.02663 | 8.964 ± 0.00674 |
| 4. | *Allianthus excelsa* | 6.891 ± 0.01323 | 12.118 ± 0.80572 |
| 5. | *Argemone Mexicana* | 3.311 ± 0.009 | 6.169 ± 0.79656 |
| 6. | *Artocarpus heterophyllus* | 7.151 ± 0.01253 | 14.132 ± 0.00233 |
| 7. | *Azadirachta indica* | 2.496 ± 0.00916 | 11.211 ± 0.00321 |
| 8. | *Bambusa vulgaris* | 2.123 ± 0.013 | 4.119 ± 0.00404 |
| 9. | *Bauhinia variegata* | 2.792 ± 0.00905 | 4.298 ± 0.00265 |
| 10. | *Butea monosperma* | 7.491 ± 0.00723 | 14.223 ± 0.0024 |
| 11. | *Callistemon accuminatus* | 3.158 ± 0.01005 | 6.263 ± 0.00436 |
| 12. | *Calotropis procera* | 13.394 ± 0.01468 | 26.212 ± 0.85494 |
| 13. | *Carissa carandas* | 2.907 ± 0.00542 | 5.427 ± 0.00498 |
| 14. | *Cassia fistula* | 6.16 ± 0.06807 | 12.183 ± 0.56381 |
| 15. | *Causonis trifolia* | 3.434 ± 0.00574 | 6.292 ± 0.57418 |
| 16. | *Chrysophyllum oliviforme* | 2.127 ± 0.016 | 5.167 ± 0.00348 |
| 17. | *Citrus limon* | 4.426 ± 0.01301 | 8.826 ± 0.00346 |
| 18. | *Cordia dichotoma* | 6.614 ± 0.00951 | 10.182 ± 0.33148 |
| 19. | *Dalbergia sisoo* | 4.324 ± 0.006 | 7.485 ± 0.53733 |
| 20. | *Datura metel* | 7.905 ± 0.00746 | 14.647 ± 0.00233 |
| 21. | *Eucalyptus globulus* | 2.610 ± 0.01051 | 5.842 ± 0.54265 |
| 22. | *Ficus benghalensis* | 8.604 ± 0.15773 | 16.65 ± 0.00231 |
| 23. | *Ficus hispida* | 14.703 ± 0.02013 | 19.5157 ± 0.28769 |
| 24. | *Ficus infectoria* | 5.595 ± 0.01048 | 11.435 ± 0.86962 |
| 25. | *Ficus religiosa* | 3.177 ± 0.00977 | 10.793 ± 0.00513 |
| 26. | *Gnaphalium polycaulon* | 4.602 ± 0.01513 | 9.155 ± 0.88016 |
| 27. | *Holoptelea integrifolia* | 5.806 ± 0.01438 | 10.926 ± 0.61849 |
| 28. | *Ipomoea purpurea* | 6.46 ± 0.01604 | 13.021 ± 0.85424 |
| 29. | *Jatropha curcas* | 5.951 ± 0.02462 | 10.13 ± 0.00346 |
| 30. | *Kalimeris indica* | 4.232 ± 0.00853 | 7.316 ± 0.00348 |
| 31. | *Lantana camera* | 5.949 ± 0.01401 | 12.049 ± 0.78493 |
| 32. | *Leucaena leucocephala* | 5.112 ± 0.0075 | 13.243 ± 0.89375 |
| 33. | *Lysimachia foemina* | 3.447 ± 0.01457 | 6.198 ± 0.33516 |
| 34. | *Madhuca indica* | 6.437 ± 0.00677 | 13.005 ± 0.81424 |
| 35. | *Mangifera indica* | 7.610 ± 0.0085 | 14.074 ± 0.74125 |
| 36. | *Millettia pinnata* | 7.170 ± 0.00746 | 15.985 ± 1.52982 |

Continued

| | | | |
|---|---|---|---|
| 37. | *Mitragyna speciosa* | 6.682 ± 0.00851 | 11.881 ± 0.60433 |
| 38. | *Moringa oleifera* | 5.589 ± 0.00651 | 10.453 ± 0.64617 |
| 39. | *Nerium oleander* | 3.906 ± 0.00539 | 6.19 ± 0.6604 |
| 40. | *Phoenix dactylifera* | 3.939 ± 0.02547 | 9.311 ± 0.00463 |
| 41. | *Phyllanthus emblica* | 3.884 ± 0.02733 | 4.967 ± 0.00353 |
| 42. | *Pithecellobium dulce* | 2.465 ± 0.00806 | 4.643 ± 0.66471 |
| 43. | *Polyalthia longifolia* | 5.496 ± 0.00901 | 10.942 ± 0.54778 |
| 44. | *Pongamia pinnata* | 4.392 ± 0.00956 | 8.682 ± 0.00536 |
| 45. | *Psidium guajava* | 5.517 ± 0.02753 | 13.127 ± 0.00296 |
| 46. | *Solanum nigrum* | 6.228 ± 0.00808 | 11.019 ± 0.88425 |
| 47. | *Syzygium cumini* | 6.431 ± 0.00419 | 14.297 ± 0.89154 |
| 48. | *Tectona grandis* | 17.447 ± 0.0196 | 23.044 ± 0.80819 |
| 49. | *Vachellia nilotica* | 4.442 ± 0.019 | 8.158 ± 0.87814 |
| 50. | *Ziziphus mauritiana* | 4.128 ± 0.026 | 9.085 ± 0.76654 |

### 3.2. Protein Content

It is well known that the soluble protein content is an important indicator of physiological status of plants. The main reason for decreasing in protein content of the selected plant species could be the disturbances in protein biosynthesis mechanisms or breakdown of protein. Similar to pigment contents, a reduction in leaf protein content was also observed at polluted sites. In present study, maximum protein content has been found in leaf of *Lantana camera* (2.156 $mg{\cdot}g^{-1}$) in unpolluted site and in polluted it was 1.014 $mg{\cdot}g^{-1}$ followed by *T. grandis* (0.793 $mg{\cdot}g^{-1}$ and 0.699 $mg{\cdot}g^{-1}$), *F. hispida* (0.788 $mg{\cdot}g^{-1}$ and 0.604 $mg{\cdot}g^{-1}$), *C. accuminatus* (0.412 $mg{\cdot}g^{-1}$ and 0.382 $mg{\cdot}g^{-1}$), *D. sisoo* (0.296 $mg{\cdot}g^{-1}$ and 0.254 $mg{\cdot}g^{-1}$), *L. leucocephala* (0.323 $mg{\cdot}g^{-1}$ and 0.248 $mg{\cdot}g^{-1}$), *C. procera* (0.750 $mg{\cdot}g^{-1}$ and 0.244 $mg{\cdot}g^{-1}$), *V. nilotica* (0.256 $mg{\cdot}g^{-1}$ and 0.226 $mg{\cdot}g^{-1}$), *C. carandas* (0.286 $mg{\cdot}g^{-1}$ and 0.203 $mg{\cdot}g^{-1}$), *P. emblica* (0.217 $mg{\cdot}g^{-1}$ and 0.193 $mg{\cdot}g^{-1}$). The lowest protein content has been found in leaf of *A. indica*, *i.e.* 0.068 $mg{\cdot}g^{-1}$ in unpolluted and in polluted area recorded value was 0.034 $mg{\cdot}g^{-1}$. Overall, the protein content is less in plant species in and around open cast mining areas as compared to control site, *i.e.* unpolluted areas (**Table 3**). Reduction in protein content in response to stress might be attributed to the breakdown of existing protein to amino acids, higher rates of protein denaturation and/or reduced de novo protein synthesis [46]. Proline accumulation could be the result of de nevo synthesis, lower utilization, and decreased degradation hydrolysis of proteins. Several researchers have reported that elevated proline levels in plants under stressful environmental conditions could impart stress tolerance by sustaining osmotic stability or cell turgor and protect cellular functions, thus checking oxidative burst in plants. An increase in proline levels under stressful environments was also reported [54] [63] [64]. Increased ammonia content in

the environment could cause stress because of its toxicity and the total protein content of plants is increased to overcome it and some of them could be considered as an urgent reactor agent. Proline contamination could reduce damage of membrane and proteins. It has been proved that the impact of pollution on plants includes destruction of pigments, reduction of cell lipid and peroxidation of unsaturated fatty acid.

**Table 3.** Protein content (mg/g FW) of plant leaves from polluted and controlled areas.

| S. No. | Plant Species | Polluted | Unpolluted |
|---|---|---|---|
| 1. | *Adenostoma lavenia* | 0.151 ± 0.0026 | 0.170 ± 0.00145 |
| 2. | *Aegle marmelos* | 0.164 ± 0.00203 | 0.183 ± 0.00208 |
| 3. | *Albizia procera* | 0.178 ± 0.00115 | 0.214 ± 0.00406 |
| 4. | *Allianthus excelsa* | 0.120 ± 0.00203 | 0.192 ± 0.00145 |
| 5. | *Argemone mexicana* | 0.078 ± 0.00203 | 0.092 ± 0.00233 |
| 6. | *Artocarpus heterophyllus* | 0.092 ± 0.00176 | 0.107 ± 0.00231 |
| 7. | *Azadirachta indica* | 0.034 ± 0.00203 | 0.068 ± 0.00115 |
| 8. | *Bambusa vulgaris* | 0.137 ± 0.00208 | 0.172 ± 0.0026 |
| 9. | *Bauhinia variegata* | 0.101 ± 0.00233 | 0.121 ± 0.00233 |
| 10. | *Butea monosperma* | 0.189 ± 0.00145 | 0.345 ± 0.0026 |
| 11. | *Callistemon accuminatus* | 0.382 ± 0.00153 | 0.412 ± 0.00088 |
| 12. | *Calotropis procera* | 0.244 ± 0.00203 | 0.750 ± 0.00176 |
| 13. | *Carissa carandas* | 0.203 ± 0.00233 | 0.286 ± 0.00265 |
| 14. | *Cassia fistula* | 0.099 ± 0.00346 | 0.195 ± 0.00208 |
| 15. | *Causonis trifolia* | 0.102 ± 0.00233 | 0.157 ± 0.00321 |
| 16. | *Chrysophyllum oliviforme* | 0.14 ± 0.00173 | 0.167 ± 0.00273 |
| 17. | *Citrus limon* | 0.188 ± 0.00265 | 0.218 ± 0.00145 |
| 18. | *Cordia dichotoma* | 0.165 ± 0.00233 | 0.287 ± 0.00346 |
| 19. | *Dalbergia sisoo* | 0.254 ± 0.00203 | 0.296 ± 0.0026 |
| 20. | *Datura metel* | 0.140 ± 0.00203 | 0.252 ± 0.00231 |
| 21. | *Eucalyptus globulus* | 0.121 ± 0.00173 | 0.163 ± 0.00321 |
| 22. | *Ficus benghalensis* | 0.155 ± 0.00203 | 0.294 ± 0.00233 |
| 23. | *Ficus hispida* | 0.604 ± 0.00233 | 0.788 ± 0.07332 |
| 24. | *Ficus infectoria* | 0.078 ± 0.00203 | 0.142 ± 0.00176 |
| 25. | *Ficus religiosa* | 0.105 ± 0.00203 | 0.191 ± 0.00145 |
| 26. | *Gnaphalium polycaulon* | 0.082 ± 0.00176 | 0.122 ± 0.00219 |
| 27. | *Holoptelea integrifolia* | 0.047 ± 0.00273 | 0.116 ± 0.00231 |
| 28. | *Ipomoea purpurea* | 0.111 ± 0.00203 | 0.152 ± 0.00208 |
| 29. | *Jatropha curcas* | 0.052 ± 0.00145 | 0.080 ± 0.00233 |
| 30. | *Kalimeris indica* | 0.090 ± 0.00176 | 0.106 ± 0.00233 |

Continued

| | | | |
|---|---|---|---|
| 31. | *Lantana camera* | 1.014 ± 0.00252 | 2.156 ± 0.00384 |
| 32. | *Leucaena leucocephala* | 0.248 ± 0.00173 | 0.323 ± 0.00467 |
| 33. | *Lysimachia foemina* | 0.070 ± 0.00145 | 0.121 ± 0.00176 |
| 34. | *Madhuca indica* | 0.119 ± 0.00265 | 0.263 ± 0.00624 |
| 35. | *Mangifera indica* | 0.087 ± 0.00208 | 0.109 ± 0.00233 |
| 36. | *Millettia pinnata* | 0.088 ± 0.00265 | 0.154 ± 0.00173 |
| 37. | *Mitragyna speciosa* | 0.096 ± 0.0026 | 0.128 ± 0.00208 |
| 38. | *Moringa oleifera* | 0.122 ± 0.00176 | 0.134 ± 0.00208 |
| 39. | *Nerium oleander* | 0.099 ± 0.00296 | 0.151 ± 0.00754 |
| 40. | *Phoenix dactylifera* | 0.108 ± 0.00555 | 0.175 ± 0.00208 |
| 41. | *Phyllanthus emblica* | 0.193 ± 0.00203 | 0.217 ± 0.00145 |
| 42. | *Pithecellobium dulce* | 0.149 ± 0.00203 | 0.192 ± 0.00346 |
| 43. | *Polyalthia longifolia* | 0.126 ± 0.00203 | 0.149 ± 0.00173 |
| 44. | *Pongamia pinnata* | 0.147 ± 0.00208 | 0.169 ± 0.00145 |
| 45. | *Psidium guajava* | 0.082 ± 0.00231 | 0.113 ± 0.0026 |
| 46. | *Solanum nigrum* | 0.115 ± 0.00203 | 0.127 ± 0.00173 |
| 47. | *Syzygium cumini* | 0.134 ± 0.00173 | 0.153 ± 0.00176 |
| 48. | *Tectona grandis* | 0.699 ± 0.00153 | 0.793 ± 0.0026 |
| 49. | *Vachellia nilotica* | 0.226 ± 0.00203 | 0.256 ± 0.00176 |
| 50. | *Ziziphus mauritiana* | 0.184 ± 0.00203 | 0.213 ± 0.0012 |

### 3.3. Carotenoid Content

Carotenoids are an assembly of fat-soluble natural pigments associated with the photosynthetic process in photosynthetic bacteria, algae and plants. Carotenoid plays a crucial role in the photosynthetic activity and shield chlorophyll from photoxidative reaction. Plant carotenoids are red, orange and yellow lipid soluble pigments found embedded in the membranes of chloroplast and chromoplast. The carotenoid content was lower in all the polluted plant species as comparison with unpolluted plant species (**Table 4**). Several workers have also reported the loss of carotenoid pigments due to the action of pollutants [46] [54]. Carotenoids prevent photo-oxidation of chlorophyll by acting as an antioxidant, but this normal defensive process of carotenoids is vulnerable to environmental stress and often results in cellular devastation, including pigment dilapidation [65]. In present study, best 10 plant species which have been found maximum carotenoid content and among highest have been recorded in leaf of *T. grandis* (0.491 $mg{\cdot}g^{-1}$) in unpolluted site and in polluted it was (0.372 $mg{\cdot}g^{-1}$) followed by *F. hispida* (0.480 $mg{\cdot}g^{-1}$ and 0.354 $mg{\cdot}g^{-1}$), *C. procera* (0.420 $mg{\cdot}g^{-1}$ and 0.322 $mg{\cdot}g^{-1}$), *B. monosperma* (0.379 $mg{\cdot}g^{-1}$ and 0.322 $mg{\cdot}g^{-1}$), *F. benghalensis* (0.324 $mg{\cdot}g^{-1}$ and 0.281 $mg{\cdot}g^{-1}$), *F. infectoria* (0.317 $mg{\cdot}g^{-1}$ and 0.281 $mg{\cdot}g^{-1}$), *C. dichotoma* (0.271 $mg{\cdot}g^{-1}$ and 0.253 $mg{\cdot}g^{-1}$), *J. curcas* (0.251 $mg{\cdot}g^{-1}$ and 0.193 $mg{\cdot}g^{-1}$), *B.*

*variegata* (0.170 mg·g$^{-1}$ and 0.143 mg·g$^{-1}$), *P. guajava* (0.294 mg·g$^{-1}$ and 0.141 mg·g$^{-1}$) respectively (Table 4). Lowest carotenoid content has been found in leaf of *L. leucocephala* and its recorded value was 0.040 mg·g$^{-1}$ in unpolluted and in polluted it was 0.028 mg·g$^{-1}$. Several studies have reported that the significant reduction in carotenoid pigments in leaf samples collected form polluted environment in a variety of plants due to their exposure to gaseous air pollutants [57] [58] [66]-[68]. Carotenoids protect photosynthetic organisms against potentially harmful photoxidative processes and are essential structural components of the photosynthetic antenna and reaction center [69].

**Table 4.** Carotenoid content (mg/g FW) of plant leaves from polluted and controlled areas.

| S. No. | Plant Species | Polluted | Unpolluted |
|---|---|---|---|
| 1. | *Adenostoma lavenia* | 0.101 ± 0.00203 | 0.132 ± 0.00203 |
| 2. | *Aegle marmelos* | 0.108 ± 0.00348 | 0.124 ± 0.00231 |
| 3. | *Albizia procera* | 0.081 ± 0.00318 | 0.106 ± 0.00296 |
| 4. | *Allianthus excelsa* | 0.109 ± 0.00233 | 0.253 ± 0.00321 |
| 5. | *Argemone Mexicana* | 0.033 ± 0.00321 | 0.062 ± 0.00353 |
| 6. | *Artocarpus heterophyllus* | 0.119 ± 0.00379 | 0.146 ± 0.0026 |
| 7. | *Azadirachta indica* | 0.075 ± 0.00273 | 0.281 ± 0.00291 |
| 8. | *Bambusa vulgaris* | 0.133 ± 0.00203 | 0.162 ± 0.00513 |
| 9. | *Bauhinia variegata* | 0.143 ± 0.00524 | 0.170 ± 0.00145 |
| 10. | *Butea monosperma* | 0.322 ± 0.00348 | 0.379 ± 0.00491 |
| 11. | *Callistemon accuminatus* | 0.123 ± 0.00176 | 0.153 ± 0.00491 |
| 12. | *Calotropis procera* | 0.322 ± 0.00328 | 0.420 ± 0.00145 |
| 13. | *Carissa carandas* | 0.125 ± 0.0026 | 0.152 ± 0.00208 |
| 14. | *Cassia fistula* | 0.104 ± 0.0026 | 0.231 ± 0.00318 |
| 15. | *Causonis trifolia* | 0.079 ± 0.00173 | 0.097 ± 0.00473 |
| 16. | *Chrysophyllum oliviforme* | 0.061 ± 0.00115 | 0.092 ± 0.00306 |
| 17. | *Citrus limon* | 0.111 ± 0.0026 | 0.133 ± 0.00231 |
| 18. | *Cordia dichotoma* | 0.253 ± 0.00173 | 0.271 ± 0.00321 |
| 19. | *Dalbergia sisoo* | 0.093 ± 0.00208 | 0.113 ± 0.00203 |
| 20. | *Datura metel* | 0.17 ± 0.00173 | 0.34 ± 0.05292 |
| 21. | *Eucalyptus globulus* | 0.054 ± 0.00145 | 0.083 ± 0.00173 |
| 22. | *Ficus benghalensis* | 0.281 ± 0.00321 | 0.324 ± 0.00233 |
| 23. | *Ficus hispida* | 0.354 ± 0.00291 | 0.480 ± 0.00233 |
| 24. | *Ficus infectoria* | 0.281 ± 0.00145 | 0.317 ± 0.00318 |
| 25. | *Ficus religiosa* | 0.082 ± 0.00203 | 0.241 ± 0.00318 |
| 26. | *Gnaphalium polycaulon* | 0.064 ± 0.00433 | 0.092 ± 0.00208 |
| 27. | *Holoptelea integrifolia* | 0.123 ± 0.00233 | 0.151 ± 0.00145 |
| 28. | *Ipomoea purpurea* | 0.083 ± 0.00173 | 0.107 ± 0.00498 |

Continued

| | | | |
|---|---|---|---|
| 29. | *Jatropha curcas* | 0.193 ± 0.0024 | 0.251 ± 0.00384 |
| 30. | *Kalimeris indica* | 0.082 ± 0.0026 | 0.105 ± 0.00173 |
| 31. | *Lantana camera* | 0.115 ± 0.00265 | 0.133 ± 0.00203 |
| 32. | *Leucaena leucocephala* | 0.028 ± 0.00145 | 0.040 ± 0.00145 |
| 33. | *Lysimachia foemina* | 0.038 ± 0.00233 | 0.058 ± 0.00145 |
| 34. | *Madhuca indica* | 0.129 ± 0.00176 | 0.153 ± 0.00233 |
| 35. | *Mangifera indica* | 0.094 ± 0.00176 | 0.103 ± 0.00186 |
| 36. | *Millettia pinnata* | 0.107 ± 0.00265 | 0.265 ± 0.0026 |
| 37. | *Mitragyna speciosa* | 0.153 ± 0.00208 | 0.172 ± 0.00145 |
| 38. | *Moringa oleifera* | 0.076 ± 0.0026 | 0.095 ± 0.00176 |
| 39. | *Nerium oleander* | 0.135 ± 0.00145 | 0.162 ± 0.00498 |
| 40. | *Phoenix dactylifera* | 0.093 ± 0.00176 | 0.29 ± 0.00231 |
| 41. | *Phyllanthus emblica* | 0.051 ± 0.00577 | 0.123 ± 0.00612 |
| 42. | *Pithecellobium dulce* | 0.089 ± 0.00361 | 0.112 ± 0.00145 |
| 43. | *Polyalthia longifolia* | 0.114 ± 0.0026 | 0.142 ± 0.00361 |
| 44. | *Pongamia pinnata* | 0.103 ± 0.00353 | 0.131 ± 0.00176 |
| 45. | *Psidium guajava* | 0.141 ± 0.00203 | 0.294 ± 0.00379 |
| 46. | *Solanum nigrum* | 0.065 ± 0.00203 | 0.090 ± 0.00203 |
| 47. | *Syzygium cumini* | 0.049 ± 0.00273 | 0.092 ± 0.0024 |
| 48. | *Tectona grandis* | 0.372 ± 0.00265 | 0.491 ± 0.00115 |
| 49. | *Vachellia nilotica* | 0.068 ± 0.0024 | 0.091 ± 0.00145 |
| 50. | *Ziziphus mauritiana* | 0.061 ± 0.0024 | 0.102 ± 0.00203 |

## 4. Conclusion

Many changes in plant physiology and growth, such as those caused by air pollution mainly the dust pollution originating from open cast mining, are biological compensatory responses to environmental stress. The main stress compensatory strategy in plants is to minimize damage from stress [70]. In fact, these changes help plants minimize stress and maximize use of internal and external resources [71]. The present study showed that the highest dust-capturing capacity was shown by *T. grandis* and it is followed by *F. hispida*, *C. procera*, *B. monosperma* and *F. benghalensis* respectively whereas the lowest is in *C. accuminatus*. The highest chlorophyll content was observed in *T. grandis* followed by *F. hispida*, *C. procera*, *F. benghalensis* and *M. indica* respectively whereas low chlorophyll content is in *B. vulgaris*. Chlorophyll measurement is an important tool to evaluate the effect of air pollutants on plants as it plays an important role in plant metabolisms and also reduction in chlorophyll content corresponds directly to plant growth [50]. Leaf chlorophyll content thus can provide valuable information about physiological status of plants. It also varies with the tolerance as well as sensitivity of the

plant species. The change in the amount of carotenoid content depends on plant tolerance towards dust. The highest protein content was observed in *T. grandis* followed by *F. hispida*, *C. accuminatus*, *D. sisoo* and *L. leucocephala* respectively whereas low protein content is in *A. indica*. The change in the amount of protein content depends on plant resistance to chemical nature of dust. Tolerance is relatively proportional to the levels of pollution, which gives variation from one species to another species and capacity to resist pollutants in the mining environment without showing any external damage or loss. Characteristics features including species tolerance on the existing environment, biochemical changes, leaf shape, petiole length, leaf hairs, phyllotaxy and plant height are essential factors influencing dust deposition. On this background, above mentioned species having the highest content of chlorophyll, protein, carotenoid and dust-holding capacity may be recommended as the first-choice species for greenbelt design in an around open cast mining area to minimize the dust load of the neighboring environment.

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## Conflicts of Interest

The authors declare that they have no conflict of interest regarding the publication of this paper.

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