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Effect of Stone Crusher Dust Pollution on Biomass of Pigeon Pea

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Abstract: Stone crusher dust produces deleterious effects on growth and development of plants. This study was done on pigeon pea plants grown on different agro-climatic conditions of Nawada district of Bihar to evaluate the effect of stone crush pollution on its biomass. This study was done on samples collected at an interval of 30 days for up to 240 days. Five plants from each group were collected at each time point. The stem and root of the collected samples were evaluated for biomass. At the initial time point, we did not observe any significant difference in biomass in both stem and root among the study groups. However, we observed significantly decreased biomass in both stem and root in plants in the affected area compared with the unaffected area at later time points (90 days onward). Stone crusher dust may affect the plants through encrustation of leaves, plugging of stomata, changes in the quantum of light absorbed by leaves, changes in pH both outside and inside the leaf as well as through modification in soil condition. Further, the significantly reduced biomass may be due to inhibition of the metabolic activity of plants in affected areas. The present study gives the evidence to the fact that stone crusher dust pollution is harmful to pigeon pea plants off all ages, irrespective of the stage of growth and development.

Keywords: Stone crusher dust, pollution, Agro ecosystem, Pigeon pea, Environment.

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1. INTRODUCTION

Cajanus cajan, commonly known as pigeon pea, red gram, Tur or as gungo peas in Jamaica is a perennial legume from the family Fabaceae.[1] The centre of origin of Pigeon Pea was most likely Asia, from where it travelled to East Africa and Latin America. It is an erect, branched, hairy shrub, 1-2 meters high. Leaves are oblong-lanceolate to the oblate plate with three leaflets. Flowers are yellow, in sparse peduncled racemes, about 1.5-cm long. The pod is hairy, 4-7 cm long, 1 cm wide, containing two to seven seeds. Since its domestication in the Indian subcontinent at least 3,500 years ago, its seeds have become a common food in Asia, Africa and Latin America.[2] India is a principal pigeon pea-growing country contributing nearly 90% of the total world production. Currently, it occupies an area of 3.85 million hectares with an annual production of 2.68 million tones.[3] It is the major grain crop of semi-arid tropics. It has high protein content and is therefore commonly used as a substitute for meat in a largely vegetarian population in India. It is consumed on a very large scale in South Asia and is a major source of protein for the population of the Indian subcontinent.[4] It is the primary accompaniment to rice or wheat bread and has the status of the staple diet throughout the length and breadth of India. In addition, to be a good source of nutrients, pulses reduce the risk of suffering cardiovascular diseases, diabetes and some types of cancer.[5] Pigeon pea contains 21.7 g protein, 1.5 g fat, carbohydrate 62.8 g, dietary fibre 15.0 g, energy 343 kcal and 130 mg calcium per 100 g of edible portion.[6] The plant produces a vast array of secondary metabolites as defense against environmental stress or other factors like pest attacks, wounds, and injuries. The complex secondary metabolites produced by plants have found various therapeutic uses in medicine from time immemorial.[3] Change in the environment can affect the metabolic activity of organisms. The changes in environment due to several factors, such as air pollution is the prominent one. The massive air pollution is due to rapid industrialization and urbanization which is becoming a cause of public concern.[6] In India, out of five major air pollutants viz., sulphur oxides, nitrogen oxides, carbon monoxide, particulate matter and oxidants, the atmospheric environment is much disturbed by sulphur oxides and suspended particulate matter.[3] The particulate matter is much prevalent in the areas where industries such a fertilizer plants, cement factories, refineries, thermal power and chemical plants are being set up at a rapid rate.[7] The high concentrations of particulates in the atmosphere over large urban and industrial areas can produce a number of general effects.[8] This in time effects the erosion and corrosion of buildings, materials, metals and also plant life. Several studies have been done on pigeon pea plants in context to environmental pollution. Broadly those studies showed the environmental pollution inversely influences the productivity of plants. As far as I know, none of the studies in pigeon pea has shown the impact of stone cursing air pollution on the biomass of pigeon pea plants. So in this study, our aim was to investigate the effect of stone crusher dust pollution on the biomass of pigeon pea growing in the vicinity of stone crusher area of Nawada District, Bihar.

2. MATERIAL AND METHODS

The present study deals with "The effect of stone crusher dust pollution on agro ecosystem." The study sites were situated in the vicinity of the stone crushers of Nawada district, Bihar (24^0 31' to 25^0 5' North latitude and 83^0 17' to 86^0 East longitude). It is approximately 265m at the mean sea level and the distance of about 180 km South-East from Patna, Bihar. There is agricultural land for rice, wheat, maize, gram, pigeon pea, sesame, sunflower, groundnut, niger, jowar, finger-millet etc. in the north-east direction of stone crushers. The rocks are collected from hills of Nawada district, Bihar, one km away from stone crushers for the preparation of small stone particles. Dust load was estimated from different distances i.e. 1 to 2 km away from emission sources in the prevailing wind direction (SW→NE) by dust collection jar method. Two plots of pigeon pea (*Cajanuscajan)* plants were selected for the present study i.e. in the vicinity of stone crusher area (stone crusher dust polluted site) and another where the dust load was zero treated as a control site. The sampling was done from both polluted as well as the unpolluted (control) area. We have collected five samples of plants in both the study groups at each time point. The study was done for 240 days at an interval of 30 days.

2.1 Sowing Of Seeds

Seeds of pigeon pea were sown in rows in 4th week of June 2010 on control and polluted sites in an area of 50 m x 50 m. The soil of control and polluted sites were pulverized and well manured. The distance between two rows was maintained 30 cm. Emergence started within 7 days. After the seedling has emerged, the wedding was done to keep a uniform distance between two plants of pigeon pea in a row.

2.2. Collection Of Plant Samples

The samples of the plant were collected from control and polluted field at the age of 30, 60, 90, 120, 150, 180, 210 and 240 days interval from the date of sowing (five samples from each group). These study subjects were lying on a transect passing through the field were carefully dug so that the root and shoot system remained intact. The plants were washed with a spray of water to remove the soil adhering to the underground parts before the plants were used for analysis.

2.3. Standing Crop Biomass

The Sampling was taken at the interval between 30 days. At each sampling date plants were selected randomly and were dug out individually up to a depth of 30 cm. Sample plants were washed carefully to remove soil from the root system. Sample plants were cut out to separate their component parts. Plants were dried in the oven at 80^0C for 48 hours. The dried samples were weighed. The average dry weight of five plants was estimated and biomass was expressed in g/m^2. The standard deviation was calculated for all the mean values.

2.4. Net Primary Productivity (Npp)

It was calculated by using the following formula:

$$NPP\ (g/m^2/day) = \frac{W_2 - W_1}{t_2 - t_1}$$

Where, W_1 and W_2 are standing crop biomass at time t_1 and t_2 respectively.

3. STATISTICAL ANALYSIS

Graph Pad PRISM-5 was used for statistical analysis. Mean and standard deviation (SD) were used for inter column analysis. Significance between two groups was calculated by unpaired two-tailed and Mann Whitney u test. A p-value < 0.05 was considered significant.

4. RESULTS

The biomass of stem (A), root (B) and overall (stem + root) (A+B) of five individual plants at each time point grown in stone crusher dust polluted area (polluted) and five plants grown in healthy condition (non-polluted) were evaluated and compared during a period of 240 days of an interval of 30 days. In stem, the initial mean biomass was 60.34 ± 7.0 g/m^2 vs. 55.92 ± 4.0 g/m^2 at day 30 (Non-polluted plants stem vs. polluted plants stem) (Table-1A and Table-2A). Gradually the gain in biomass was observed in the stem of both the groups of plants. The maximum biomass was observed 3820.44 ± 351.9 g/m^2 vs. 2855.36 ± 130.8 g/m^2 at day 210 (Table-1A and Table-2A). After that, the biomass of stem in both the groups of plants start decreasing and at day 240 was 3414.16 ± 170.6 g/m^2 vs. 2696.0 ± 94.3 g/m^2 (Table-1A and Table-2A). Overall at the early time points (30 days to 90 days), we did not observe any significant difference in biomass in the stem of both the groups of plants. However, after day 90 the significant difference in biomass of stem in both the groups of plants was observed and the level of significance was highest at day 210 (Figure 1A). The significant difference in biomass of both the plant groups was still maintained at day 240 (when the biomass of both the groups of plants started decreasing). Similar to stem we have also evaluated the biomass of root in both the groups of plants. Initial mean biomass in root was 8.67 ± 0.6 g/m^2 vs. 8.27 ± 0.6 g/m^2 at days 30 (polluted plants root vs. non-polluted plants root) (Table-1A and Table-2A). Gradually the gain in biomass was observed in the root of both the groups of plants. The maximum biomass was observed 285.18 ± 8.7 g/m^2 vs. 212.64 ± 8.7 g/m^2 at day 180 (Table-1A and Table-2A). After that, the biomass of the root in both the groups of plants start decreasing and at day 210 was 266.34 ± 12.7 g/m^2 vs. 202.96 ± 12.7 g/m^2 and at 240 was 225.62 ± 8.1 g/m^2 vs. 173.32 ± 8.1 g/m^2 (Table-1A and Table-2A). Overall at the earliest time points (30 days), we did not observe any significant difference in biomass in the root of both the groups of plants (the biomass was almost the same). However, after days 30 the significant difference in biomass in the root of both the groups of plants was observed and the level of significance was highest at day 180. The significant difference in biomass in root of both the plant groups was still maintained at day 240 (when the biomass of both the groups of plants start decreasing) (Figure-1B). Finally, we combined the biomass of stem (A) and root (B) in both the groups of plants to get the overall biomass (A+B) of the plants. Further, compared the observed biomass between them. We observed the change in biomass was more influenced by the biomass of stem and following the trend of change in biomass of stem. In overall biomass at the initial time point (till 90 days) we did not observe any significant difference after that the significance was pronounced even though the biomass was decreased at the later time point (day 210 and day 240) (Table 1B and Table 2B).

Table 1A: Standing crop biomass (g/m^2) of control pigeon pea at various stages of growth period (time points)

Age (days)	Stem (A)						Root (B)					
	A1	A2	A3	A4	A5	Mean(± SD)	B1	B2	B3	B4	B5	Mean(±SD)
30	67.3	54.3	56.9	68.6	54.6	60.34±7.0	7.8	8.36	9.36	8.66	9.2	8.676±0.6
60	77.1	76.3	81.2	71.3	72.6	75.7±3.9	19.6	19.6	17.87	16.8	21.6	19.094±1.8
90	189.3	201.4	195.2	185.3	182.3	190.7±7.6	56.3	51.8	47.9	48.6	47.6	50.44±3.6
120	1117.2	896.3	997.6	889.8	983.6	976.9±92.5	177.3	144.6	187.3	167.5	183.6	172.06±17.9
150	2073.6	2223.1	2288.6	2386.5	2206.8	2235.72±114.9	234.6	243.4	211.9	224.3	227.6	228.36±11.7
180	2997.6	3204.8	3007.6	2989.6	3321.3	3104.18±150.9	288.6	276.5	278.2	298.3	284.3	285.18±8.7
210	4036.6	3317.6	3675.6	4236.2	3836.2	3820.44±351.9	267.6	287.6	256.3	257	263.2	266.34±12.7
240	3671.4	3361.6	3368.9	3206.6	3462.3	3414.16±170.6	229.7	227.6	217.3	236.1	217.4	225.62±8.1

Observed individual biomass (g/m^2) of pigeon pea plant grown in control environmental condition: (A) Showing the biomass of stem (B) Showing the biomass of root.

Table 1B: Over all biomass (g/m^2) of standing crop of control pigeon pea at various stages of growth period (time points)

Age (Days)	Stem: A (Mean ± SD)	Root: B (Mean ± SD)	Biomass = A+B (Mean ± SD)
30	60.34 ± 7.0	8.676 ± 0.6	69.01 ± 1.3
60	75.7 ± 3.9	19.094 ± 1.8	94.79 ± 5.7
90	190.7 ± 7.6	50.44 ± 3.6	241.14 ± 11.2
120	976.9 ± 92.5	172.06 ± 17.9	1148.96± 110.4
150	2235.72 ± 114.9	228.36 ± 11.7	2464.08 ± 126.6
180	3104.18 ± 150.9	285.18 ± 8.7	3389.36 ± 159.6
210	3820.44 ± 351.9	266.34 ± 12.7	4086.78 ± 364.6
240	3414.16 ± 170.6	225.62 ± 8.1	3639.78 ± 178.8

Observed total biomass [(mean ±SD of stem + mean ± root) of pigeon pea plant grown in control environmental condition: (A) Showing the total biomass of stem (B) Showing the total biomass of root.

Table 2A: Standing Crop biomass (g/m²) of polluted Pigeon Pea at various stages of growth Period (time points)

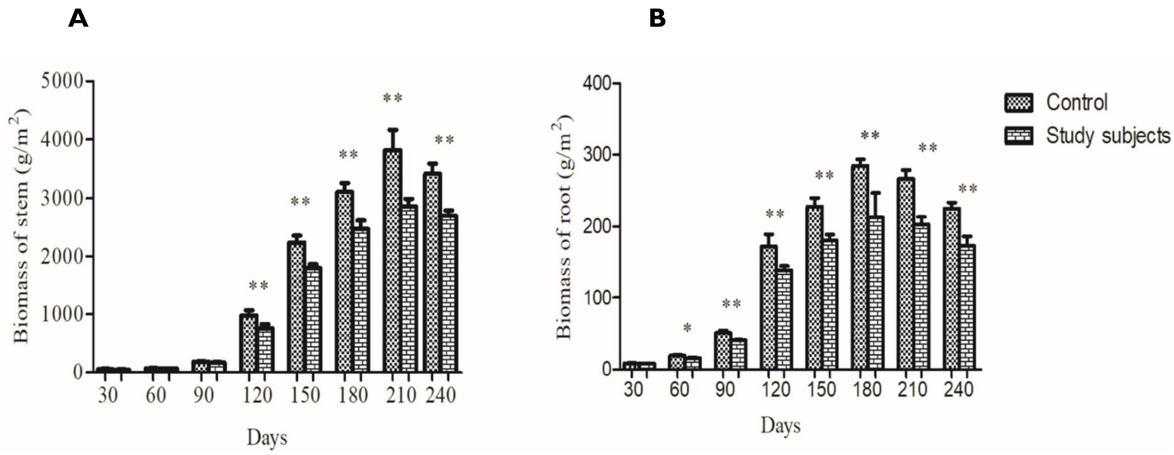
Age (days)	Stem (A)						Root (B)					
	A1	A2	A3	A4	A5	Mean(± SD)	B1	B2	B3	B4	B5	Mean
30	57.2	56.3	50.9	61.6	53.6	55.92±4.0	7.8	7.36	8.36	8.66	9.2	8.276±0.6
60	76.6	77.8	72.3	75.6	74.3	75.32±2.1	16.2	15.1	16.3	15.8	17.6	16.2±1.8
90	186.3	187.6	164.3	157.6	167.2	172.6±13.5	39.6	39.4	41.2	41.7	41.2	40.62±3.6
120	856.3	676.2	776.2	764.2	744.1	763.4±64.7	142.6	147.3	133.4	136.2	134.6	138.82±17.0
150	1776.2	1713.2	1786.4	1896.5	1806.8	1795.82±66.2	187.6	176.4	169.9	189.7	176.4	180±11.7
180	2543.2	2424.2	2687.3	2336.2	2331.4	2464.46±151.4	221.6	152.2	231.2	236.6	221.6	212.64±8.7
210	2867.5	2934.6	2973.6	2864.7	2636.4	2855.36±130.8	196.7	221.3	198.6	196.8	201.4	202.96±12.7
240	2734.3	2666.5	2836.4	2586.4	2656.4	2696±94.3	166.7	167.8	186.3	158.2	187.6	173.32±8.1

Observed individual biomass (g/m²) of pigeon pea plant grown in stone crushed polluted environmental condition: (A) Showing the biomass of stem (B) Showing the biomass of root.

Table 2B: Over all biomass (g/m²) of standing crop of polluted Pigeon Pea at various stages of growth period (time points)

Age (Days)	Stem: A (Mean ± SD)	Root: B (Mean ± SD)	Biomass = A+B (Mean ± SD)
30	55.92 ± 4.0	8.276 ± 0.6	64.19 ± 4.6
60	75.32 ± 2.1	16.2 ± 1.8	91.52 ± 3.9
90	172.6 ± 13.5	40.62 ± 3.6	213.22 ± 17.1
120	763.4 ± 64.7	138.82 ± 17.0	902.22 ± 81.7
150	1795.82 ± 66.2	180 ± 11.7	1975.82 ± 77.9
180	2464.46 ± 151.4	212.64 ± 8.7	2464.46+212.64
210	2855.36 ± 130.8	202.96 ± 12.7	3677.1 ± 143.5
240	2696 ± 94.3	173.32 ± 8.1	2869.32 ± 102.4

Observed total biomass [(mean ±SD of stem + mean ± root) of pigeon pea plant grown in stone crushed polluted environmental condition: (A) Showing the total biomass of stem (B) Showing the total biomass of root.



Significant values depicted in figure with star. For one star (*) P= 0.05, for two star (**) p < 0.01 and three star (***) p <0.0001.

Fig1: Comparative of biomass of Pigeon pea at different age: (A) Biomass of stem (B) Biomass of root.

5. DISCUSSION

Cultivation of agriculture crops is essential for the sustaining of life on earth. The productivity of crop depends on several factors like; the texture of the soil, availability of nutrients in the soil, availability of sunlight, quality of air (air pollution) etc.[9] The texture of soil depends on the percentage of sand, silt and clay present in the total composition of the soil.[10] The texture is essential for retaining and availability of water and air to the plant growth. Sunlight is essential for photosynthesis and reproductive growth of the plant. The length of sunlight directly influences the biomass of the plant.[11] The quality of air (air pollution) is detrimental to the plant reproductive growth as well as biomass. The mining and stone crushing activities have substantial effects on environmental quality.[12] The emission of dust produced from stone crushing, contaminate both water and air and also limit the availability of light to the plant for their metabolic activity.[13] The concentrated contaminated environment injured the crop ranging from visible markings on the foliage to reduced growth and yield to the premature death of the crop.[14] The development and severity of the injury depend not only on the concentration of the particular pollutant but also on a number of other factors. These include the length of exposure to the pollutant, the plant species and its stage of development as well as the environmental factors conducive to a build-up of the pollutant and to the preconditioning of the plant, which makes it either susceptible or resistant to injury.[15, 16] Stone pelleting is one of the major industrial activity experiencing since a long time in Nawada district. The produced by-products (particulate matter, Oxidant, sulfur dioxide) through this activity inversely influence the vegetation. Particulate matter such as cement dust, magnesium-lime dust and carbon soot deposited on vegetation can inhibit the normal respiration and photosynthesis mechanisms within the leaf that leads to decreased biomass of plants. This particulate matter is mainly deposited on leaves (aerial parts of the plant) so its influence is more on aerial part than the root (underground part of the plant). Cement dust may cause chlorosis and death of leaf tissue by the combination of a thick crust and alkaline toxicity produced in wet weather. The dust coating also may affect the normal action of pesticides and other agricultural chemicals applied as sprays to foliage. In addition, accumulation of alkaline dust in the soil can increase soil pH to levels averse to crop growth. Several studies have been done in stone crushing and plant productivity [15,16] and most of the studies showed the negative effect of stone crushing on the productivity of plants. This was the unique study done on pigeon pea, in which we had shown the biomass of pigeon pea was significantly decreased in the stone shush neighboring areas plants.

6. CONCLUSION

The present study gives evidence to the fact that stone crusher dust pollution is harmful to pigeon pea plants off all ages, irrespective of the stage of growth and development based on this study it may be concluded that stone crusher dust produced deleterious effects on growth and development of pigeon pea. The stone crusher dust affects the plant's growth, encrustations of leaves, plugging of stomata, changes in the quantum of light absorbed by leaves, changes in pH both outside and inside the leaf. So, the above finding concludes that pigeon pea could suffer a loss in size in terms of both quality and quantity in stone crusher dust polluted areas of Nawada district of Bihar.

7. ACKNOWLEDGEMENT

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8. AUTHORS CONTRIBUTION STATEMENT

R Kumar, P Kumar and PA Kumar all equally contributed to conceptualizing this study. Further, R Kumar and P Kumar collected the samples, performed all the experiments, analyzed the data and wrote the manuscript. PA Kumar reviewed the manuscript. All authors read and approved the final manuscript.

9. CONFLICT OF INTEREST

Conflict of interest declared none.

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