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Effect of cement kiln dust pollution on black gram (*Vigna mungo* (L.) Hepper)

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Abstract. Effect of cement kiln dust pollution on black gram (*Vigna mungo*) has been studied by comparing plants of polluted as well as from non-polluted areas. Due to cement kiln dust accumulation on exposed parts of the plant, there was a decrease in height, phytomass, net primary productivity and chlorophyll content. Quantitative estimations and histo-chemical localization indicate lowering of metabolites in dusted plants as compared to control one. In polluted plants, damaged leaves show increase in stomatal index and trichome frequency and decrease in stomatal frequency. Cement kiln dust accumulation on plant surface showed decrease in the number and size of flowers which finally affected the yield to a great extent in the dusted plants.

Keywords. Black gram; cement kiln dust; phytomass; pollution; yield.

1. Introduction

Cement kiln dust is considered as one of the most dangerous dusts of industrial origin since it not only forms a crust, but also enters into a chemical reaction with the atmospheric moisture and is thus, chemically active (Czaja 1962). The cement kiln dust is reported to be harmful to vegetation, causing considerable reduction in agricultural production, primarily affecting fertilization and starch production (Darely 1966). Studies on the phytotoxic effects of different kinds of particulate pollutants has been carried out by a number of workers from time to time. The particulate dust falling on the leaves is said to cause foliar injuries, reduction in yield, changes in the rate of photosynthesis, transpiration and uptake and accumulation of mineral elements from soil (Lerman and Darely 1975). *Vigna mungo* (L.) Hepper commonly known as black gram, an economically important Fabaceae member has been chosen to study the various effects of cement kiln dust pollution in detail, since there is a lacuna in the studies of particulate pollution on economic crop plants.

2. Materials and methods

Seeds of *V. mungo* were procured from the market. Seedlings were raised in the University botanical garden in a plot of 16 sq. m size divided into two halves of equal size. The seeds were sown at 15 cm intervals in rows with a distance of 10-cm between two rows. Plants grown in one plot served as control, whereas those in the other plot were uniformly dusted with $10\,g\,m^{-2}\,day^{-1}$ cement kiln dust. Five plants were sampled at each sampling time at 20 days interval from both control and experimental plots and washed thoroughly in water, rinsed in distilled water and blotted with filter paper prior to further use. The height of plant were recorded during the experiment period. Net primary productivity (NPP) was determined by dividing the total phytomass value by the age of the plant. Leaves were sampled to determine parameters such as chlorophyll content (Mac Lachlan and Zalik 1963), proteins (Layne 1957), starch (McCreddy *et al* 1950), total sugars (Dubois *et al* 1956), reducing sugars (Miller 1972), lipids (Bragdon 1951; Folch *et al* 1957), amino acids (Moore and Stein 1948), total phenols (Bray and Thorpe 1954) and orthodihydroxy phenols (Arnow 1937). Epidermal peels were obtained by direct peeling method. Peels were then used for epidermal studies and also for histochemical tests such as protein (Chapman 1975), starch (Johansen 1940), lipid (Bronner 1975), peroxidase (Graham and Karnovsky 1966), succinic dehydrogenase (Pearse 1972) and cytochromeoxidase (Burstone 1959).

3. Results

3.1 *Morphological parameters*

The results obtained of cement kiln dust dusted and non-polluted plants were compared as regards height, number of leaves per plant, size of leaves, thickness of lamina, branching of stem, phytomass, NPP, number of flowers and yield (table 1).

3.1a *Height of plant*: The height of control and dusted plants after 20 and 120 days was 16 and 157 cm, and 13 and 100 cm respectively. There is a reduction of 36% in height of dusted plants after 120 days.

3.1b *Root length*: The root length of control and dusted plants after 20 and 120 days was 10·2 and 30·0 cm, and 8·6 and 20·0 cm respectively. There is a reduction of 33·33% in root length of dusted plants after 120 days. The decrease in root length of dusted plants also affects the root nodules. There is a decrease of 50% in root nodules of dusted plants.

3.1c *Branches*: Branching was noticed only after the plants attained the age of 40 days. The branches of control and dusted plants after 40 and 120 days were 3 and 25, and 0 and 10 respectively. There is a significant reduction in number of branches of dusted plants after 120 days. This indicates that in control plants the branching started earlier than dusted plants.

3.1d *Leaves*: Number of leaves in the control and dusted plants after 20 and 120 days were 4 and 120, and 3 and 50 respectively. A reduction of 55·33% in number of leaves in dusted plants after 120 days was recorded. Reduced number of leaves in dusted plants was also associated with the conspicuous decrease in the thickness of lamina and leaflet size.

Cement kiln dust was found accumulated on both surfaces of the leaflets. However, accumulation of dust particles were more on adaxial surface compared to abaxial surface. Leaflets retained 2·05 mg of dust per sq. cm on their exposed surfaces. Leaflets get reduced in size and become curved. The texture of the leaflets become brittle.

3.1e *Phytomass*: Phytomass values showed a decrease in dusted than control plants. There is a reduction of 62·3% in stem, 64·0% in leaf and 63·67% in root

Table 1. Morphological parameters of control and dusted plants of *V. mungo*.

Age of plant		Height of plant	Root length	Bran-ches	Leaves	Phytomass	NPP	Root/shoot ratio	Flowers	Fruits
20	C	16	10·2	—	4	3·873	0·194	0·64	—	—
	D	13	8·6	—	3	3·368	0·168	0·66	—	—
40	C	36·5	18·5	3	27	31·138	0·778	0·51	—	—
	D	26	14	0	10	20·749	0·521	0·54	—	—
60	C	50	23·5	17	70	90·810	1·514	0·47	—	—
	D	33·9	16·6	6	34	51·862	0·864	0·49	—	—
80	C	120	26·5	20	100	197·090	2·464	0·22	5	—
	D	79	18	8	50	105·729	1·322	0·23	3	—
100	C	150	29	25	130	198·796	1·988	0·19	30	10
	D	97	19·6	10	70	86·642	0·866	0·20	15	5
120	C	157	30	25	120	141·206	1·177	0·19	90	80
	D	100	20	10	50	51·922	0·433	0·20	45	40

Average of 5 replicates. C, Control; D, dusted.

phytomass in dusted plants after 120 days. Total phytomass values exhibited an increase up to 80 days of growth. After 120 days a reduction of 63·23% in total phytomass of dusted plants is noticed.

3.1f *NPP*: The NPP values of control and dusted plants after 20 and 120 days were 0·194 and 1·177 g, and 0·168 and 0·433 g respectively. There is a reduction of 63·21% in NPP of dusted plants after 120 days. The significant decrease in NPP of dusted plants is also correlated with decrease in phytomass.

3.1g *Root/shoot ratio*: It showed a continuous decrease with an increase in age of plant in control and dusted plants. The ratio of control and dusted plants after 20 and 120 days was 0·64 and 0·19, and 0·66 and 0·20 respectively. Root/shoot ratio of dusted plants after 120 days was enhanced by 5%.

3.1h *Flowers*: Flowering started after 60 days of growth period. The number of flowers in control and dusted plants after 80 and 120 days was 5 and 90, and 3 and 45 respectively. There is a 50% reduction in number of flowers of dusted plants at 120 days age.

3.1i *Yield*: Dusted plants at 120 days age showed 50% reduction in number of flowers. This leads to a 50% reduction in fruit set and ultimately yield. Fruiting started after 80 days of growth period. The number of mature fruits in control and dusted plants after 100 and 120 days was 10 and 80, and 5 and 40 respectively.

3.2 *Biochemical estimations* (table 2).

3.2a *Chlorophyll content*: The total chlorophyll content, chlorophyll *a* and chlorophyll *b* exhibited an increase with an increase in age of plant up to 80 days growth which later decreased. The percentage of reduction in dusted plants chlorophylla *a* and total chlorophyll content increased with an increase in age of plant, however, chlorophyll *b* decreased with an increase in age of plant.

The total chlorophyll content of control and dusted plants after 20 and 80 days was 1·555 and 2·245 mg/g, and 1·391 and 1·785 mg/g respectively which later decreased to 0·762 and 0·583 mg/g in control and dusted plants after 120 days. There was 24·49% reduction in total chlorophyll content of dusted plants after 120 days. The decrease in total chlorophyll content of dusted plants is also correlated with the decrease in chlorophyll *a* and chlorophyll *b* contents.

3.2b *Total protein content*: Total protein content of control and dusted plants after 20 and 80 days was 0·519 and 0·258 mg/g, and 0·135 and 0·191 mg/g respectively, which later decreased to 0·202 and 0·135 mg/g in control and dusted plants after 120 days. Total protein content of dusted plants after 120 days is decreased by 33·16%.

3.2c *Starch content*: The starch content of control and dusted plants after 20 and 80 days was 1·305 and 4·007 mg/g, and 1·188 and 3·250 mg/g respectively, which later decreased to 2·691 and 1·832 mg/g in control and dusted plants after 120 days. Reduction of 31·92% starch content was observed in dusted plants after 120 days.

Table 2. Biochemical parameters of control and dusted plants of *V. mungo*.

Age of plant (days)		Total chloro-phyll content (mg/g)	Total protein content (mg/g)	Starch content (mg/g)	Total sugar content (mg/g)	Reducing sugar content (mg/g)	Lipid content (mg/g)	Amino acid content (mg/g)	Total phenol content (mg/g)	O.D. phenol content (mg/g)
	C	1·555	0·159	1·305	5·145	0·827	9·390	1·031	0·702	0·174
20	D	1·391	0·135	1·188	4·676	0·775	8·710	0·893	0·641	0·161
	PR	10·55	15·09	8·97	9·12	6·28	7·24	13·38	8·69	7·47
	C	1·722	1·75	2·509	16·196	3·394	13·170	1·296	0·749	0·291
40	D	1·495	0·146	2·182	14·374	2·893	10·470	1·090	0·688	0·265
	PR	13·18	16·57	13·03	11·25	14·76	20·50	15·89	10·81	8·93
	C	1·925	0·198	2·818	33·196	5·173	17·190	2·302	0·840	0·365
60	D	1·605	0·151	2·291	26·790	4·136	16·370	1·844	0·719	0·328
	PR	16·62	23·73	18·70	19·29	20·05	4·77	19·89	14·40	10·13
	C	2·245	0·258	4·007	45·976	7·115	19·470	3·039	1·407	0·479
80	D	1·785	0·191	3·250	34·523	5·209	21·341	2·350	1·179	0·415
	PR	20·49	25·96	18·89	24·91	26·79	8·77	22·67	16·20	13·36
	C	1·930	0·215	3·981	42·556	6·280	16·870	2·786	0·851	0·379
100	D	1·529	0·156	2·852	30·172	4·271	19·160	2·082	0·694	0·313
	PR	20·78	27·44	28·35	29·10	32·00	11·95	25·27	18·45	17·41
	C	0·762	0·202	2·691	36·125	4·151	13·180	1·600	0·769	0·328
120	D	0·583	0·135	1·832	23·512	2·637	17·396	1·145	0·575	0·263
	PR	23·49	33·16	31·92	34·91	36·47	24·23	28·44	25·23	19·82

Average of 5 replicates. C, Control; D, dusted; PR, per cent reduction.

3.2d *Sugar content*: Total sugar and reducing sugar content exhibit an increase with an increase in age of control and dusted plants. Reduction of 34·91% total sugar content and 36·47% reducing sugar content was observed in dusted plants after 120 days.

3.2e *Lipid content*: Quantitative values of lipid content in control plants is higher than that of dusted plants up to 60 days. Lipid content becomes higher in dusted than control plants after 60 days. Lipid content of dusted plants after 120 days is increased by 24·23%.

3.2f *Amino acid content*: The amino acid content of control and dusted plants after 20 and 80 days was 1·031 and 3·039 mg/g, and 0·893 and 2·350 mg/g respectively, which later decreased to 1·600 and 1·145 mg/g in control and dusted plants after 120 days. Amino acid content of dusted plants after 120 days is reduced by 28·44%.

3.2g *Phenolic content*: The quantitative values of total phenols and OD phenols increased up to 80 days of growth period with an increase in age of plant which later decreased. The total phenol and OD phenol content of dusted plants after 120 days were reduced by 25·23 and 19·82% respectively.

3.3 *Histochemistry*

Histochemical localization of proteins and starch showed a decreased activity, whereas lipids showed increased activity in dusted plants as compared to control plants. Localization of enzymes like succinic dehydrogenase, cytochrome oxidase and peroxidase revealed less activity in dusted plants with reduction in metabolites.

3.4 *Epidermal studies*

Leaves of *V. mungo* are amphistomatic. Epidermal cells are polygonal with wavy anticlinal walls. Epidermal cell frequency decreases in polluted plants in comparison with control plants. Epidermal cell frequency is more on abaxial surface than adaxial on both control and dusted plants (table 3).

Table 3. Epidermal features of non-polluted and polluted plants of *V. mungo*.

			Stomata					Trichome		
					Stomatal types					
		Epidermal cell frequency	Stomatal index	Stomatal frequency	Paracytic	Anomocytic	Abnormal	Trichome frequency	Eglandular trichomes	Glandular trichome
Ad	NP	496	17·6	106	96·4	3·6	—	41	74·8	25·2
	P	315	22·4	91	93·4	2·4	4·2	65	72·8	27·2
Ab	NP	797	24·6	260	97·0	3·0	—	24	28·6	71·4
	P	642	27·4	242	94·3	4·2	1·5	30	36·6	63·4

Average value of 5 replicates.
Ad, Adaxial; Ab, abaxial; NP, non-polluted; P, polluted.

In polluted plants few abnormal stomata were observed. Stomatal frequency was reduced in polluted plants, while stomatal index increased in polluted plants. The stomatal index was more on abaxial surface in both control and dusted plants (table 3).

Trichomes were observed on both the surfaces, however, their density was more on adaxial than on abaxial surface. Trichome frequency increases in polluted plants. Eglandular and glandular clavate type of trichomes are observed in both surfaces. Eglandular trichomes are dominent on adaxial surface, while glandular clavate type is dominent on abaxial surface of both control and dusted plants (table 3).

4. Discussion

Among particulate air pollutants, cement kiln dust is a potential phytotoxic pollutant in the vicinity of a cement factory. In the present study, formation of a hard thick encrustation of cement kiln dust on the plant surfaces was observed in cement kiln dusted plants (Oblisami *et al* 1978; Armbrust 1986).

In the present study, cement kiln dust was found to reduce height of plant in dusted plants. Reduction in height of plant in responce to environmental pollution due to decreased photosynthesis per unit leaf area and/or enhanced leaf senescence, increased respiration. The inhibition in growth is due to reduced intensity of light energy available for photosynthesis through coatings of leaves (Mishra 1982; Emanuelson 1984; Indhirabai *et al* 1988, 1989). Root length as well as nodulation in roots is also reduced due to increased pH of soil and the presence of calcium in dust which is added to soil. The number of branches in dusted plants was found to be decreased. The height of plant and internodal elongation were reduced by cement kiln dust pollution (Indhirabai *et al* 1988, 1989). Due to formation of cement crust on leaves, polluted plants showed a decrease in lamina thickness and size of leaf.

The phytomass and NPP values of cement kiln dust dusted plants showed lesser values than control plants. This indicates a reduction in photosynthesis of dusted plants (Singh and Rao 1981). Singh and Rao (1981) reported that changes in the root/shoot ratio of dusted plants showed a trend similar to that of control plants. The values in dusted plants were always higher than control plants (Borka 1980).

Under the effect of cement kiln dust the acidic secretion of stigma turned into alkaline, a condition which is unfavourable for pollen germination which leads to poor fertilization and yield (Borka 1986). From gross morphological measurements of control and dusted plants it is quite apparent that dusted environmental condition had an adverse .effect on the vegetative growth, flowering and fruiting potential of plants thus, indicating a considerable reduction in the productivity of the plant.

Cement kiln dust, on entering into leaf tissues, the chemically active solution caused partial denaturation of the chloroplasts and a decrease in pigment content in the cells of damaged leaves (Borka 1986). Higher levels of cement kiln dust pollution considerably decrease the growth and metabolic activities. One of the most characteristic biochemical feature of cement kiln dust dusted plants is a reduction in total chlorophyll content (Singh 1979; Singh and Rao 1981; Pawar *et al* 1982; Rajachidambaram 1983).

Present observation on the reduction in protein content in dusted plants is parallel to that of many workers (Prasad 1980; Agrawal 1982; Pawar *et al* 1982). It thus appears that the total protein content is also a suitable indicator of particulate pollution level. Closing of stomata not only prevented the inward diffusion of necessary amount of CO_2, but because of higher temperature caused by reduced transpiration, inhibits the phosphorylation of sugars and thereby the removal of starch from the site of origin. The increase in lipid content in dusted plants appears to be an adaptation by plants against pollution (Malhotra and Khan 1978).

Chemical information can be best expressed in morphological terms through histochemical methods (Malik and Singh 1980). Constantinidou and Kozlowski (1979) reported that *Ulmus* seedlings exposed to air pollutants showed a decrease in carbohydrates, proteins and lipid contents which also is evident in dusted plants. The decrease of these metabolites leads to reduction in growth and finally yield. Percy and Riding (1981) reported similar results in *Pinus* needles.

A decrease in the number of stomata in leaf epidermis in polluted plants indicates a favourable adaptation (Sharma and Butler 1973; Yunus and Ahmed 1980) to regulate the transpiration as well as the limited and controlled entry of harmful pollutants into plant tissues. The more number of trichomes help in protecting the leaf from direct exposure to sun rays, thus lowering the leaf temperature and reducing the rate of metabolic reaction associated with the destruction of plant tissues.

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