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The Effect of Cement Dust Pollution on Celosia Argentea (Lagos Spinach) Plant

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Abstract: The effect of cement dust pollution on heavy metal uptake, growth, chlorophyll content, vitamin content and metal accumulation of *Celosia argentea* (Lagos spinach) was investigated. Loamy soil polluted with Portland cement (100:1) had significant amount of iron, calcium, magnesium, aluminium, silicon and sulphur (in form of sulphates) which are prominent in cement dust. Zinc and copper levels in the polluted soil though not present in cement dust, were also significantly higher in concentration in the polluted soil. The presence of cement in the polluted soil did not affect the germination time of *C. argentea* seeds. Upon growing, the spinach plants were polluted with 10.2 g m^{-2} cement dust at 3 days interval, between the 40th and 100th days of their growth. The results showed that cement dust had no significant effect on the germination of seeds of *C. argentea*. There was a significant reduction in shoot length and total leaf area of polluted plants. The dry weight of the polluted plants was significantly lower throughout the period of analysis than those of the control plants. The frequency and size of the epidermal cells and stomata of the polluted leaves were greatly modified. The level of vitamin A was reduced by 62%, vitamin B_2 by 55% and vitamin C by 24%. Though the iron and calcium concentrations of the polluted plants were raised by 78 and 26%, respectively, there was a significant accumulation (at $p = 0.05$) of heavy metals such as aluminium (Al), copper (Cu) and zinc (Zn) in the polluted plants. These results may discourage the practice of vegetable gardening in areas under cement dust pollution.

Key words: Cement dust, *C. argentea*, vitamin, heavy metals, iron, calcium

INTRODUCTION

Cement dust has been shown to adversely affect the soil ecological communities. Soils surrounding cement factories, especially downward areas, exhibit elevated pH levels (Adamson *et al.*, 1994; Mandre, 1997; Mandre *et al.*, 1998). In a soil composition study performed on the surroundings of some cement factories, it was found that there were elevated levels of chromium, silica, iron and calcium with contamination levels decreasing dramatically with distance from the factories. These compositions affect vegetative growth (Asubiojo *et al.*, 1991; Ade-Ademilua and Umebese, 2007).

Portland cement contains 3-8% aluminium oxide, 0.5-0.6% iron-oxide, 60-70% calcium oxide, 17-25% silicon oxide, 0.1-4% magnesium oxide and 1-3% sulphur trioxide (Lea, 1970; Ade-Ademilua and Umebese, 2007). Cement-Kiln dust affects plant growth mostly by the formation of crusts on leaves, twigs and flowers. The crust is formed because some portion of the settling dust consists of the calcium silicates, which are typical of the clinker (burned limestone) from which cement is made. When this dust is hydrated on the leaf surfaces, a gelatinous calcium silicate hydrate is formed, which later crystallizes and solidifies to a hard crust. When the crust is removed, a replica of the leaf surface is often found, indicating intimate contact of dust with the leaf. Prolonged dry periods during

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the time dust is deposited provide no opportunity for hydration and crusts are not formed. Dust deposits, which are not crusted, are readily removed by wind or hard rain (Darley *et al.*, 1966; Mandre *et al.*, 1999).

Celosia argentea (Lagos spinach) is a popular leafy vegetable in the Old World tropics. It is a member of the Amaranthaceae, a family closely related to Chenopodiaceae. *C. argentea* is the most important species of the genus. It is of African origin, although another cultivated form, variety *Cristata kunize*, was probably domesticated in Asia. *Celosia* has become dispersed throughout the tropics. In its centre of origin, Senegal to Cameroun in Africa, it is both cultivated and wild, found as a weed or rudeval in open waste places in forest zones. It is an annual herb with wide morphological variation attaining up 2 m in height with a characteristic flowers pike, elongated and pointed and usually silvery-white but often coloured pink to red. This characteristic provided the generic name *Celosia* from the Greek Kelos meaning burning. The plant flowers throughout the year in West Africa and leaves (and stems) provide a ready source of vegetables or pot herbs (Hutchinson, 1967; Tindall, 1983). The morphological variations in *C. argentea* are shown in plant height, leaf size and florescence size as well as colour. Tindall (1983) outlined the environment response of a green and a red form of cultivated *C. argentea* as tolerant to a wide range of soil conditions; although a high level of organic material in the soil is required for the production of optimum yields, particularly for the green form. *Celosia* is notably used in research studies in a development project located at the Nigerian Horticultural Research Institute (NHRI) founded by UNDP. In West and Central Africa, apart from use as a vegetable in soups, leaves can be used to flavour rice and for feeding animals. In Zaire and in Senegal, a fibre is prepared from the stems (Sreeramulu, 1982; Faboya, 1983; Tindall, 1983).

Celosia argentea was chosen as the experimental plant because it is commonly cultivated by the subsistent farmers residing around the Portland cement factory in Ewekoro for their families consumption. The vegetable is consumed because of its nutritive value particularly the vitamin content; however it is also a good source of calcium and iron (Badra, 1993). The study reported in this paper is therefore to determine the effect of cement pollution on the growth of *C. argentea* plants with particular interest on the nutritional content of the plants. Are the plants really safe for consumption?

MATERIALS AND METHODS

The experiment was carried out between 2002 and 2003. Loamy soil from the Botanical garden of the University of Lagos, Lagos-Nigeria was used for planting the seeds. A batch of soil was mixed with Portland cement at a ratio of 100:1 as polluted soil while another batch serving as control soil was unmixed loamy soil. *Celosia argentea* (Lagos spinach) seeds were obtained from Lagos Agricultural Inputs Supply Company limited (Farm Service Centre), Oko-Oba, Lagos.

Metal Constituents in the Soils

Soil samples were collected from polluted and control soils 7 days and then 69 days after sowing. The soil pHs were measured using a pH meter (Jenway model). The concentration of iron, zinc, copper, calcium, magnesium, aluminium, silicon and sulphur as sulphate in the soil were determined according to the procedures outlined by Allen *et al.* (1974).

Planting Procedure

Cultivation was carried out at the Botanical garden of the University of Lagos, Lagos-Nigeria. Two sets each of twenty-one planting pots of the same size (19 cm in diameter by 19 cm deep) filled with 4 kg per pot of either polluted or control soil. The sets were kept in separate greenhouses. *C. argentea* seeds were sown in each 21 pots set. Each set was arranged in 3 rows of 7 pots with each row serving as replicate. Watering was carried out every other day. A week old seedlings were thinned down to 8 per pot to allow enough space for growth.

Aerial Plant Pollution

Forty gram of Portland cement were blown over plants grown in polluted soil using an electric fan at 3 days interval from the time the plants were a week old. Cement dust were blown from both ends of the greenhouse to cover an area of 3.92 cm^2. Aerial pollution of the plants was carried out throughout the period of the experiments.

Growth Analysis

Plants were randomly uprooted from each row every week from 41 days after sowing. Shoot lengths of a plant per row were measured with a meter rule. Total leaf area of a plant per row was determined by calculating the area of traced leaf outlines on a graph paper. Dry weights (oven dried for 3 days at 80°C) of whole plants were taken using electric weigh balance (Mettler Toledo Model AB 204).

Structural Study of the Leaf Epidermis

The leaf epidermis was prepared by soaking the leaves from plants from each row in nitric acid overnight. The peels were removed and rinsed in several changes of water. They were stained in safranin O, rinsed in water to remove excess stain and mounted with glycerine. The photomicrographs of the stained adaxial and abaxial epidermis were than taken using Yashica 107 multiprogram camera mounted on a Reichert microstac (IV) research light microscope. The quantitative characters of the epidermis of each sample which include the number of epidermal cell per field view, size of the epidermal cell (length and width), number of stomata per field view and the stomata length and width were assessed by examining the slide prepared under the light microscope.

Determination of Chlorophyll Content

One gram of *C. argentea* leaves from plants from each row were rolled up and placed in boiling tubes filled with 15 mL of 80% ethanol. Chlorophyll content analyses were carried out as described by Arnon (1949).

Vitamin Content of Leaves

The quantities of Vitamins B_2, A and C in leaves were analysed at 97 days after sowing. Leaf tissues from each row of plants were prepared and analysed according to the methods described by the Association of Official Analytical Chemists (AOAC, 1980).

Chemical Analysis of Leaves and Stems

Finely ground (0.5 g) dried leaves and stems of plants from each row at 69 days after sowing were used in analysing the quantity of metals present in the leaves and stems of both control and polluted plants, according to the method described by Anonymous (1992).

Statistical Analysis

With each row in the two sets serving as replicate, analysis of 3 replicates per set were carried out and results recorded in averages. Using a one-way classification, analysis of variance (ANOVA) of the polluted and control plants were done to test the level of significance between the plants at $p = 0.05$.

RESULTS

The polluted soil had a significantly higher pH than the control soil. The level of iron, calcium, magnesium, aluminium, silicon and sulphur as sulphate was significantly higher in the polluted soil than in the control soil; while there was no significant difference between the level of zinc and copper in the polluted and control soils. By 69 days after sowing, the levels of iron, zinc, copper, aluminium, silicon and sulphur in form of sulphate were significantly higher in the polluted soil than in control while calcium and magnesium concentrations in both polluted and control soils showed no significant difference (Fig. 1).

The seeds of *Celosia argentea* sown in the polluted and control soils germinated at the same time (3 days after sowing. The leaves of *C. argentea* under cement pollution did not show any symptoms of injury, however, the plants in the control soil flowered a week (13th week) earlier than the polluted plants.

The control plants grew significantly higher than the polluted plants throughout the course of growth (Fig. 2). The control plants also had a significantly larger total leaf area per plant than the polluted plants throughout the course of growth (Fig. 3).

The dry weight of both control and polluted plants increased with time. The control plants however, had a significantly higher dry weight than the polluted plants over time except at 62 days after sowing (Fig. 4).

The stomata frequencies of the upper and lower epidermis as well as the stomata index of the upper epidermis of polluted plants are significantly higher than in control plants. Cell length and width of the upper epidermis of polluted plants were significantly higher than those of the control plants while the parameters were significantly higher in the lower epidermis of control plants. However, the frequency of the upper epidermal cells was significantly higher in control plants while the parameter was significantly higher on the lower epidermis of polluted plants. There was no significant difference in the stomata length of plants from both sets on either epidermal side (Table 1).

The control plants had significant higher concentration of all vitamins analysed than the polluted plants (Fig. 5). The comparison between the levels of accumulation of iron, zinc, copper, calcium, magnesium, aluminium, silicon and sulphur as sulphate in leaves and stems of plants at 69 days after sowing grown under polluted and control conditions are shown on Fig. 6. All the elements in the stems and leaves were significantly higher in polluted plants than in control plants with the exception of calcium and aluminium levels in the stems that were not significantly different in both control and polluted plants. In comparison of the level of metals in accumulated in the stem against

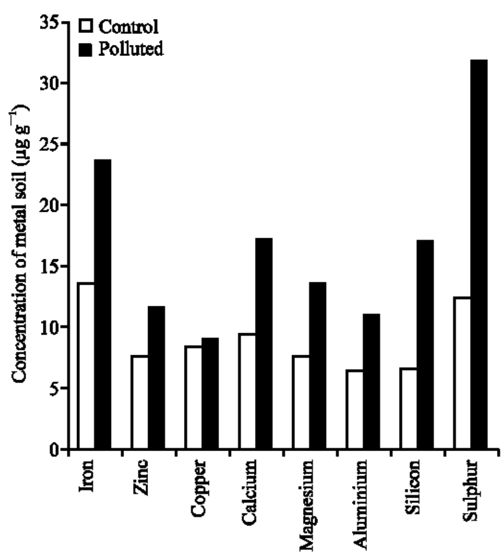

Fig. 1: Concentration of metals in polluted and control soil before planting

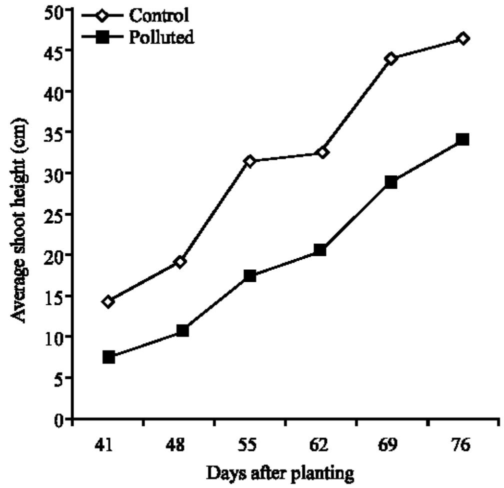

Fig. 2: Average shoot height of the control and polluted plants over time

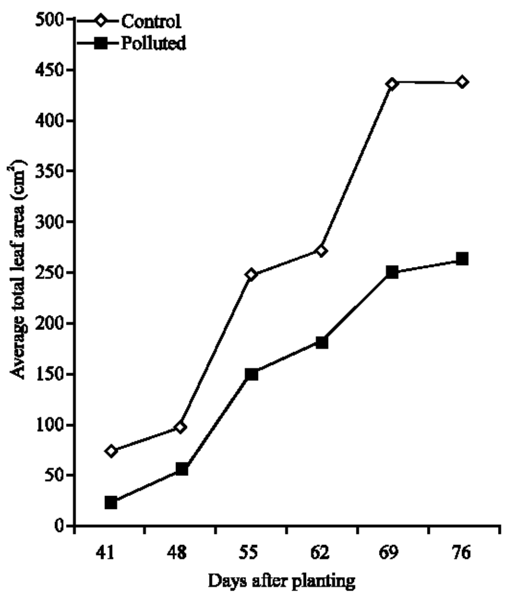

Fig. 3: Average total leaf area of control and polluted plants over time

Table 1: The quantitative characters of the upper and lower epidermis of the leaves of the polluted and control plants

	Upper epidermis		Lower epidermis	
Parameters	Control	Polluted	Control	Polluted
Stomata frequency (No. mm^{-2})	28.80±1.40a	82.50±2.40b	75.80±1.80a	11.96±2.00b
Epidermal cell frequency (No. mm^{-2})	342.50±7.50b	242.10±4.70a	214.20±6.00a	302.10±6.00b
Stomata index	7.76±0.09a	25.42±0.07b	26.14±0.08a	28.36±0.08a
Stomata length (μm)	71.17±0.74a	69.01±1.15a	79.68±1.59a	71.53±1.04a
Epidermal cell length (μm)	172.78±4.37a	197.69±5.55b	196.81±5.44b	164.20±0.65a
Epidermal cell width (μm)	77.36±2.88a	120.46±4.23b	113.38±3.31b	100.37±2.56a

Means followed by the same letter(s) are not significantly different at $p = 0.05$, based on the analysis of variance (ANOVA)

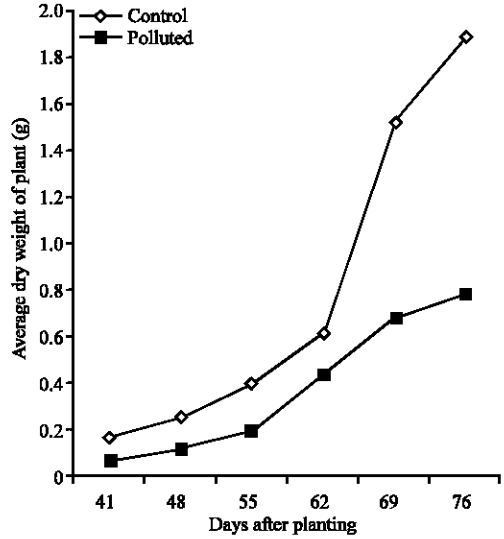

Fig. 4: Average dry weight of control and polluted plants

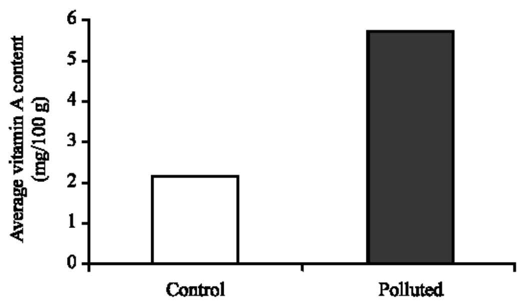

Fig. 5: Concentration of Vitamin A, B and C in the polluted and control plants at 97 days after planting

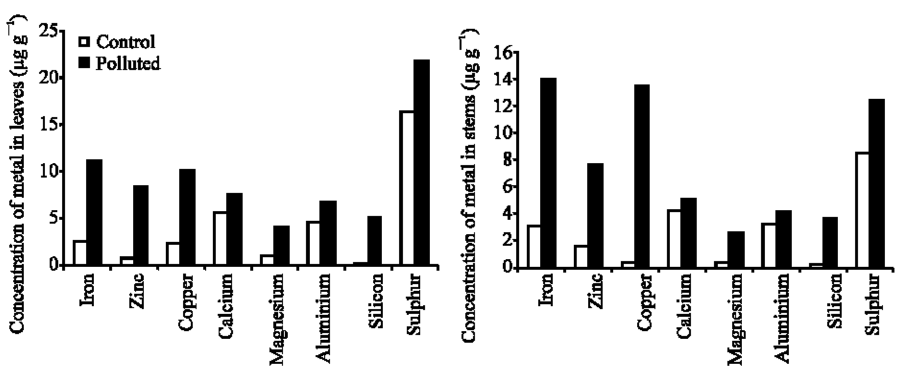

Fig. 6: Concentration of metals in stems and leaves of control and polluted plants at 69 days after planting

those in the leaves of plants, polluted plants accumulated significantly higher levels of zinc, calcium, magnesium, aluminium, silicon and sulphur as sulphate in the leaves while more of iron and copper were observed in significant amount in the stems. On the other hand, the control plants accumulated significant amount of copper, magnesium, aluminium and sulphur in form of sulphates in the leaves and the a significant level of zinc and silicon in the stems. There was no significant difference between the level of calcium and iron accumulated in both leaves and stems of control plants.

DISCUSSION

The effects of cement dust on growth, epidermal layouts, vitamin content, as well as the heavy metal accumulation of *Celosia argentea* (Lagos spinach) were investigated.

The pH of the control and cement-polluted soils were alkaline but that of the polluted soil was more alkaline. Similar studies on cement dust pollution show elevated levels of soil pH (Adamson *et al*., 1994; Mandre, 1997; Mandre *et al*., 1998). According to Mandre (1997) and Singh and Rao (1981), when plants polluted with cement dust are watered, the dust forms a solution that had been found to be highly alkaline (pH 10.4). The incorporation of this cement solution into the polluted soil might be the factor responsible for the higher pH in the polluted soil. This has been found to be due to most of the calcium in the cement dust which are in from of oxide, hydroxide and carbonate formed lime that further increase the alkalinity of the soil from the pH 8.82 before the pollution to the pH 10.10 at the end of the pollution (Lerman, 1972).

Iron, calcium, magnesium, aluminium, silicon and sulphur (in form of sulphates) that are prominent in cement dust were found to be higher in concentration in the polluted soil. This indicates the extent to which the soil was polluted by Portland cement dust. The concentrations of zinc and copper in the polluted and control soils though not significantly different before planting the seeds, became significantly higher in the polluted soil than the control soil by 69 days after planting. Ade-Ademilua and Umebese (2007) have pointed out that metal to metal association could cause an increase in the concentration of other metals (absent in cement dust) in the polluted soil over time. Forstner (1995) also pointed out that 70% of metal contaminated soils involve two or more metals and the possibility of synergistic effects may be of considerable importance at some heavy metal-contaminated sites.

The results obtained showed that cement dust had no significant effect on the germination of seeds of *C. argentea*. This was similar to the result obtained by Ade-Ademilua and Umebese (2007) when *Phaseolus vulgaris* L. seeds were sown in cement-polluted soil around West African Portland Cement Company at Ewekoro, Ogun State.

The significant reduction in shoot length and total leaf area observed in the polluted plants has also been reported in the works of Singh and Rao (1981), Ayanbamiji (1996) and Iqbal and Shafœg (1998). The reduction may be due to toxic effect of aluminium which Rout *et al*. (2000) stated that once inside the cells, aluminium could inhibit root absorption and growth in both aluminium sensitive and tolerant plants.

The dry weights of polluted plants was significantly lower throughout the period of analysis than those of the control plants. The significant decrease in vegetative growth of polluted plants may be an indication of a reduction in photosynthesis of polluted plants which could be explained on the bases of quantitative as well as qualitative changes in the incident light available for photosynthesis in cement-encrusted leaves (Bohne, 1963), of interruption in gaseous through stomatal clogging (Darley *et al*., 1966; Lerman, 1972), of reduction in transpiration in terms of the absorption of minerals from soil and inhibition of intracellular processes (Singh and Rao, 1981).

The cement dust caused the epidermal cells and stomata of the polluted leaves to become modified. The higher stomata frequency and index in the leaves of the polluted plants indicate morphological modification on the leaves. According to Ayanbamiji (1996), these may be adaptations for gaseous exchange and transpiration since the surfaces are covered by cement dust.

The adverse effect of cement dust on the polluted plants resulted in about 62, 55 and 24% reduction in vitamin A, B_2 and C contents, respectively. This shows how much the nutritive value of *C. argentea* growing in the surroundings of cement factory would be reduced in terms of its vitamin content. The results presented in this paper show that it is not safe to feed on *C. argentea* or such vegetables growing under cement dust pollution. The pollutant did not only cause marked reduction in vitamins levels, but also increased the concentration of heavy metal such as Fe, Zn, Cu, Mg, Al, Si and S (in form of sulphate) in the plants leaves and stems. According to Clark (1995), when plants with high levels of heavy metals are consumed, the metals become bio-accumulated in the body over time, that is, they remain in the body in an unchanged state and are continuously accumulated during the life of an organism causing bio-magnification which may cause various health problems including cardiac arrest synonymous with aluminium toxicity and kidney damage associated with copper toxicity. The growth of *C. argentea* plants was significantly affected by cement dust pollution and even where this is overlooked, the high accumulation of heavy metals plus reduction in vitamin content of the vegetable are evidences that the practice of vegetable gardening around the cement factory is a dangerous act, as far as the health of the consumer is concerned.

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