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Effect of Cadmium on Seed Viability of *Vigna unguiculata*

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Abstract

Cadmium, a heavy metal pollutant of growing global concern, was investigated for its effect on grain seed viability using V*igna unguiculata*. The cowpea seeds were germinated after treatment in solution containing varying concentration of cadmium chloride ($CdCl_2.H_2O$). The concentrations of cadmium (Cd) in the solution used for the treatment were 0.00ppm, 0.80ppm, 8.00ppm, 40.00ppm, 100.00ppm and 180.00ppm. The percentage germination at 120 hours germination time and the rate of increment in shoot height between 120 and 168 hours were determined. Results shows that the percentage germination and rate of increment in shoot height decreased as cadmium level in the treatment solution increased. There were however no growth at 100 and 120 ppm. The lethal concentration of cadmium for 50% of the viable seeds (LC_{50}) in the treatment solution appears to be at about 40 ppm.

Key words: Cadmium, cowpea, viability, germination.

Introduction

Concerns about environmental hazards have stimulated research to evaluate the effect of pollutants on the biosphere. Among the numerous pollutants, Cadmium, an element with no known beneficial biological function is of major concern. With increasing population, civilization, metallurgical advancement and world development, industrial utilization of cadmium containing compounds has accelerated the rate of mobilisation and distribution of cadmium which is far in excess of natural abiotic cycling process leading to a general increased deposition of cadmium in both aquatic and terrestrial environment with resultant accumulation in the biota and biosphere (Babich and Stotzky, 1978). Environment accumulation of chemical pollutants such as heavy metals have been found to interfere with certain ecological processes and energy chain like decomposition, growth, energy

generation and transformation and transmission processes such as photosynthetic and chemosynthetic processes through the trophic levels. The various ecological interactions like the plant-plant, plant-microbe, plant-animal, microbe-microbe, animal-microbe, plant-soil, microbe-soil, etc, and various biochemical cycling at the molecular levels are however not excluded (Babich and Stotzky, 1978). Abnormal levels of essential or nonessential nutrient in the body of an organism have been found to impair growth and development. In general, macronutrients are much less toxic than micronutrients and their concentration can be raised appreciably above normal optimum without significantly affecting growth. On the other hand, the margin between sufficiency and toxicity is very narrow for most micronutrients and notably for most heavy metals [Jowett, 1958 and 1964]. The sensitivity of different plants to high concentration of individual element varies greatly and it is the toxicity of such elements that inhibits the colonization by many plants of slag heaps and other industrial metallurgic waste [Jowett, 1958 and 1964].

Cadmium occurs mainly as natural components of minerals in the earth crust with an average concentration of 0.18 ppm. The most common Cadmium containing minerals are greenockite (Cadmium sulphide) (CdS, - hexagonal), hawleyite (CdS,- cubic), xanthochroite (CdS – coating, amorphous), cadmoselite (Cadmium selenide) (CdSe), monteponite (cadmium oxide) (CdO), octavite (cadmium carbonate) ($CdCO_3$), and saukovite (cadmium metacinnabar) (Hg/CdS - cubic) (Babich and Stotzky, 1978). Pure Cadmium metal does not exist in nature, but minerals containing Cadmium are associated with zinc ores, such as zinc sulphides, zinc oxides, zinc silicate and polymetallic zinc ores (Pb-Zn, Cu-Zn, Pb-Cu-Zn). Zinc to cadmium ratio ranges from 100:1 to 1000:1 in these ores (Babich and Stotzky, 1978). However organic compounds containing cadmium are unstable and have not been detected in nature [Athanassiadis, 1969; Lagerwerff 1972]. Cadmium background level in the soil ranged from 0.03-0.3 ppm [Stewart *et al*, 1974; Onweremadu *et al*, 2008; Akinola *et al*, 2008]. The concentration of cadmium in fresh water is generally less than 0.001 ppm and average on about 0.00015 ppm. In the atmosphere, cadmium exists as particulates probably with oxides of cadmium predominating, but cadmium levels in urban atmosphere are usually higher than nonurban atmosphere (Friberg *et al*, 1974).

Measurable amount of cadmium occur in many soils, animals and plant materials, and an increasing attention is been paid to its concentration in these materials for biological, medical, geochemical, and agricultural prospecting [Stewart *et al*, 1974]. Studies have shown that cadmium tend to accumulate in plant tissues at concentrations exceeding that of the soil solution [Onweremadu *et al*, 2008]. Plants tissues like roots, shoots, trunks and leaves been studied and cadmium is seen as a cumulative toxicant by most scientists. Previous studies on the effect of cadmium on seeds have been restricted to seedlings that have already germinated. This work was designed to look at some effect of cadmium

accumulation in polluted or contaminated seeds with respect to germination of a quiescent seed. The choice of *V. Unguiculata*, a typical tropical/subtropical annual crop, initially staple to tropical Africa but now to the tropical region of the world, was informed due to its large cultivation in and consumption in most industrial cities of Nigeria, such as Kano and Kaduna, which also are located in region where significant metallurgic activities are ongoing. Farmers in these regions are also known to depend heavily on fertilizers for improved crop yield.

Materials and Methods

Dried cowpea (Vigna unguiculata) seeds (white seeds) were obtained from Oba market, Benin City, Nigeria. All reagents were analar grade and were products of Merck Chemical Co., Darmstadt. All glassware were products of Pyrex England.

Preparation of cowpea: The dry seeds were steeped in solutions containing 0, 0.8, 18, 40, 100, and 180 ppm of cadmium for one and a half hour. Floating seeds were skimmed off. The steeped grains were sown on wet cotton wool in corresponding pre-labeled Petri-dishes. 14 seeds were sown in each Petri-dish and experiment carried out in replicate of three. Germination was done in the light at room temperature (about 25^0C) for 168 hours and analyses were done at intervals as germination progressed.

Growth Parameters: Percentage germination was computed from the number of seeds that germinated per replicate. The germination rate was determined by measuring the height of shoots at 120 and 168 hours of germination.

Results and Discussion

The results of cadmium effect on the seed are as shown in Table 1. The results show more than 50% reduction in the number of seeds that germinated from treatment with up to 40 ppm, with close to 0% germination at 100 ppm. The same pattern was observed in the rate of growth of the shoot. The decrease in percentage germination obtained from this study may be due to loss of viability because of decreased energy generation by the embryo. Energy generation is very important for seed germination and its blockage could affect protein, RNA and DNA synthesis as well as mitosis, since energy is required for these processes to occur (John and van-Laerhoven 1976).

Growth retardation as observed has been reported for many organisms including plants (Babich and Stotzky, 1978, John and van-Laerhoven 1976). Growth retardation is caused by decrease in cell enlargement and division. The inhibition of cell enlargement and division by cadmium is probably due to depression of growth promoters mainly through enzyme inactivation and depression or direct inhibition of cell division by interfering with the cell membrane integrity. The inhibition of cell division may be by the inhibition of mitosis through interference with the formation of mitotic

apparatus [Brachet and Mirsky, 1961]. Inhibition of protein synthesis, DNA replication and energy generation could also inhibit cell division. Cadmium probably inhibited mitosis by binding to the –SH groups in the protein molecules which build up the spindles or mitotic apparatus. Previous studies on the inhibition of –SH groups of such proteins by inhibitors such as fluoride, iodoacetic acid, chloroacetophenone and colchicines have been found to inhibit mitosis in meta-phase because the formation of the spindles is prevented [Brachet and Mirsky 1961]. Cadmium could also affect the plasticity and fluidity necessary for division of meristematic cells. Cadmium ion, Cd^{2+}, like other divalent ions like Ca^{2+}, could reduce cell memberane permeability and fluidity which is necessary for cell division.

At 40 and 100 ppm the emerged radicles were brownish and stunted with swellings from base to tip. The elongation of the radicles soon stopped without emergence of the shoot or withering of the emerged shoot. A similar effect has been reported for copper (Kopittke and Menzies 2006).

In general, cadmium concentration above 18 ppm reduces viability by close to 20% while concentration close to 40 ppm appears to reduce seed viability or inhibit germination by more than 50% and this could represent the ecological dose 50% (EcD50) of Cadmium for cowpea farm. Worse is the fact that cadmium as most heavy metals is a cumulative toxicant. A concentration of up to 0.39 ppm has been reported for the Warri River, Nigeria, 5.88 ppm for some Amaranth plants in Benin city and 0.65m -0.81 in the tissues of *Talinum triangulare* in Lagos (Ayenimo *et al* 2005, Onweremadu *et al* 2008, Akinola *et al* 2008). These are well over WHO permissible level of 0.1 mg/Kg or ppm (Onweremadu *et al* 2008).

In conclusion, it is very apparent that cadmium pollution or contamination in seeds is very detrimental to seed viability and germination. In this age of world economic crisis and food insecurity, the threat of heavy metal pollution or contamination of agricultural produce is of paramount consideration. Cadmium with no know beneficial use to man is of major concern and effort should be made my government of agrarian metallurgic communities practicing urban and peri-urban agriculture to ensure strict monitoring of cadmium emission and contamination of soil and farm produce in order to minimise its threat to increase agricultural yield and food production. Further work is recommended in area of mechanisms of action in the inhibition of enzymes and cell division.

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Table 1: Effect of Cadmium on seed germination (Growth parameters).

Cadmium Concentration (ppm or µM)	% Germination at 120 hrs	Rate of Germination i.e. increase in shoot height between 120 and 168 hrs (cm/day)
0.00	100.00	2.99
0.80	97.61	1.96
8.00	92.87	1.68
18.00	83.34	1.48
40.00	42.86	0.82
100.00	4.76	0.19
180.00	0.00	0.00