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Uptake of manganese, iron, copper, zinc and chromium by *Amaranthus cruentus* L. irrigated with untreated dye industrial effluent in low land field

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ABSTRACT

This study evaluated impact of untreated dye effluent on heavy metal uptake by *Amaranthus cruentus* L. under field condition. Amaranths grown for two consecutive dry seasons were irrigated with dye effluent concentrations of 0 (control) 10, 20, 30 and 40%. Effluent concentrations were analyzed for physico-chemical and heavy metal properties. The result showed that heavy metals taken up and accumulated in amaranths tissues increased significantly ($p \leq 0.05$) with dye effluent concentration. Heavy metals accumulated more in edible shoots than roots except chromium. Bioaccumulations of heavy metals in 2012 were in several folds higher than in 2011 dry season. In the second season, regardless of effluent sources, dye concentration of 20% gave the highest accumulations of Manganese (Mn), Iron (Fe) and Zinc (Zn) in the edible shoots. The highest accumulations of heavy metals were higher than 0.3 mg kg^{-1} allowable limits in vegetables by Food and Agricultural Organization/World Health Organization/Federal Environmental Protection Agency. Irrigation of vegetable with untreated dye effluent should be discouraged due to potential health risks on human and general contamination of the environment.

1. Introduction

Irregular pattern of rainfall experienced in the recent time in most part of Africa including Nigeria due to climate change and declining water quality have led to drying up of most streams and rivers used for dry season cropping. In addition to this challenge, competition among domestic, industrial and agricultural users of surface water especially in the dry season have made farmers to rely on any available water even polluted ones for crop production. Most farmers in Nigeria depend on water from perennial streams and rivers to grow their vegetables during the dry season when natural precipitation ceases [1]. Meanwhile, some of the perennial streams and rivers water used for crop irrigation during the dry season in Abeokuta Southwestern Nigeria have been polluted with dye effluent [2]. Different concentrations of dye industrial effluents can have different effects on crop growth, development and metal uptake when used as a source of irrigation water. Irrigation of field crops especially during the dry season, with effluents polluted water may provide alternative source of plant nutrients, higher yield, and reduced cost of fertilizer in addition to water supply. Besides, it is considered to be an important aspect of pollution removal from the environment [3,4]. However, the use of wastewater for agriculture may also be marred with several constraints due to various problems such as soil salinity, interaction of chemical constituents of the waste with the uptake of nutrients and changes in soil properties and microflora [5]. The practice may also have negative impact on the quality of the crops grown and on the consumers of such crops. Wastewater influence on crops depends upon the quality of the wastewater, type of wastewater, nature of crop grown and the overall farm water management practice [6].

Amaranth is one of the most important green leafy vegetable in Nigeria. The nutritional benefits of *Amaranthus cruentus* as a good and cheap source of minerals, vitamins and fiber which act as antioxidants has made the vegetable popular in the diet of Nigerians. Moreover, the high demand for amaranth during the dry season and corresponding high profit made by poor resource farmers compared to rainy season have led to growing of amaranth on banks of perennial streams and rivers [1,2]. Meanwhile,

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amaranth has been considered as one of the leafy vegetable that has the ability to accumulate heavy metals and genotoxic compounds at elevated amounts in its tissues when grown in contaminated soil and environment [7–9].

Plants growing on effluent-polluted soil have the ability to accumulate varieties of potentially toxic elements from the soil environment [2,10,11]. Leafy vegetables in particular can accumulate higher amounts of heavy metals as compared with fruit vegetables [7]. Uptake of the metal ions is an essential part of plant nutrition but the process of metal uptake and accumulation by plants depends on factors such as the concentration of available metals in the soil, solubility sequence and the plant species [12]. Consumption of vegetables grown in such contaminated media constitutes an important route of animal and human exposure [13]. Amaranth is a leafy vegetable, easy to cultivate and is a very popular delicacy in southwestern Nigeria. It is a relatively hardy vegetable that can grow on marginal lands with minimal agronomic maintenance. Its importance in the diets of many has made it command higher price in the dry season when it value doubles what obtains in the rainy periods. However, when toxic heavy metals are ingested in an unsafe concentrations through vegetables, it may lead to accumulation of these metals in kidney and liver [14] leading to cardiovascular, nervous system, kidney and bone diseases [15]. Meanwhile, contamination of food materials by heavy metals has been noted to be germane in food quality assurance [16–19]. Hence, monitoring heavy metals accumulation in vegetables is needed especially in dye effluents based irrigation systems where dye polluted stream water is the only alternative for farmers producing vegetables in low land field during the dry season in order to meet market demand. This study therefore aimed at assessing the impact of dye effluents concentrations on heavy metal uptake by the edible and non edible parts of amaranth under field condition.

2. Materials and methods

2.1. Location and description of experimental site

The field study was carried out at the back of Adire/Kampala market at Asero, Abeokuta South Local Government Area of Ogun State Southwestern Nigeria, located at 7.17058°N, 3.37882°E and 125 m above sea level. The experimental plot was sited upstream the riverbank at Asero, during the dry seasons in 2011 and 2012, respectively. Weather data of the two seasons are shown in Table 1.

2.2. Collection and preparation of dye effluents for irrigation

Effluents from three major local dyeing industries at Asero, Itoku and Kemta in Abeokuta were collected directly in 120 L plastic drums at discharge points for irrigation purposes. The effluent from each location was diluted with appropriate volume of fresh water to prepare 10%, 20%, 30% and 40% effluent concentrations. Water from the adjoining stream collected 100 meters away-(upstream) from the point of effluent discharge was used for the effluent dilution and also served as the control (0%). Effluent concentrations were prepared in 100 L plastic drums weekly for irrigation.

2.3. Analysis of dye effluents

Sub-samples of freshly prepared concentrations of dye effluent and freshly collected water sample from the stream (in 2 L plastic containers) were transported in coolers containing ice block to laboratory for analyses. The samples were stored in refrigerator at 4 °C pending analysis. The physico-chemical properties of the dye effluents and stream water samples were determined following standard methods for the examination of water and wastewater [20]. The pH was determined with pH meter glass electrode. Electrical conductivity (EC) and the total dissolved solid (TDS) were measured with EC/TDS meter. The dissolved oxygen (DO) in the samples was determined before and after an incubation period of five days in the dark at temperature of 20 °C by the alkaline-azide modification of Winkler's method. Biological oxygen demand (BOD5) was estimated from the DO values before and after incubation periods. The chemical oxygen demand (COD) was determined by the titrimetric method. The sulphate (SO_4^{2-}) was determined using turbidimetric method by reading the absorbance of samples at 425 nm on a UV–vis spectrophotometer (model: UV mini-1240-vis Shimadzu Corporation Analytical and Measuring Instruments Division, Kyoto, Japan). Following colou development in samples, nitrate (NO_3^-) content was measured using phenoldisulphonic acid method and read on a UV–vis spectrophotometer at 410 nm. The heavy metals in the samples were determined by passing sample solution through 125 mm Whatman filter paper (Sigma–Aldrich, Taufkirchen, Germany) [20–23]. Thereafter concentration of Fe, Mn, Zn, Cu and Cr in the filtrates were read on Buck Scientific atomic absorption spectrophotometer (AAS: 210VGP model; Buck Scientific, Inc., East Norwalk, CT, USA).

2.4. Experimental design

The experiment was a split-plot arrangement in a Randomized Complete Block Design (RCBD) with three replicates. Main-plot treatments consisted of 3 sources of dye effluents from Asero, Itoku and Kemta while sub-plot treatments were five concentrations of the effluents, (0%, 10%, 20%, 30% and 40%), respectively. Each plot was an elevated vegetable bed measuring $1 \times 1\ m^2$ with 2 m alleys between main-plots and 1 m between sub-plots treatments.

2.5. Cropping, irrigation and harvesting of the amaranths

In both dry seasons, *A.cruentus*L. was sown by drilling the seeds in well-prepared beds at a distance of about 10 cm between rows and covered lightly with soil. After planting, each bed was watered three times in the first one week after planting (WAP) with ten liters of clean fresh water collected upstream the adjoining Asero

Table 1
Some weather indicators observed at Federal University of Agriculture Abeokuta Agrometeorological station during the two amaranth cropping reasons.

Month	2011 season					2012 season				
	Temperature (°C)			Rainfall	Relative Humidity	Temperature (°C)			Rainfall	Relative Humidity
	Max.	Min.	Mean	(mm)	(%)	Max.	Min.	Mean	(mm)	(%)
January	34.3	20.1	27.2	0.00	65.9	34.0	20.0	27.0	0.00	75.2
February	34.6	23.1	28.9	139.8	78.7	33.9	23.7	28.8	67.2	70.5
March	34.1	24.3	29.2	23.9	80.0	34.3	23.9	29.1	67.7	79.3

Cropping dates were between January 3 and February 14 in 2011 and January 4 and 15 February in the 2012 seasons, respectively. Rainfalls recorded were after harvesting in February of both seasons.