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HEAVY METAL ACCUMULATION IN SOIL AND SUBSEQUENT UPTAKE BY AMARANTHUS (*Amaranthus cruentus* (L.) IRRIGATED WITH DYE INDUSTRIAL EFFLUENT

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ABSTRACT

This study assessed the impacts of untreated dye effluent collected from three dyeing sites on soil heavy metal accumulation, uptake by root and accumulation in amaranthus shoot. Dye effluents collected at discharge points on the sites were diluted with fresh water at 0 %, 25 %, 50 % and 100 % concentrations. Each dye effluent concentration was applied at the rate of 200 ml three times in a week to amaranthus seedling earlier grown for one week with fresh water. The amaranthus was harvested at 6 weeks after planting (WAP), separated into its edible (shoot) and non-edible (root) portions. Tissue concentrations of plant parts were analyzed and uptake was determined. At dye effluent concentration of 25 %, bioaccumulation of heavy metals in amaranthus shoot was significantly higher ($p < 0.05$) than fresh water irrigation. Iron and Zn accumulation in shoot was also higher than 0.30 mg kg^{-1} allowable limits by WHO/FAO/FEPA in vegetables. Dye effluent of 100 % concentration from the three sources and 50 % from Kemta caused death of amaranthus seedlings. Irrespective of sources and concentration, dye effluent increased heavy metal accumulation in soil significantly. Consumption of vegetable irrigated with dye effluent could pose risks to human health.

Key words: concentration; discharge point; dye effluent; dyeing; untreated

INTRODUCTION

Industrial effluent can have both beneficial and detrimental effects on crops when used as a source of water for irrigation purposes. The presence of high concentrations of nitrate and sulphates among other essential nutrients in the dye effluent provides the potential benefits for crop plants. These nutrients could stimulate protein formation and other chemical compounds needed for seedling growth and crop development (Yousaf *et al.,* 2010; Oguntade *et al.,* 2015). However at higher concentration of effluent, crops including amaranthus could also respond adversely depending on the sources of the effluent and the toxicity of its constituents (Nrioula, 2003; Oguntade *et al.*, 2015).

Dyes are synthetic carbon based organic compounds which often contain toxic heavy metals and effluent generated from dyeing and could be phytotoxic at higher concentrations (Balakrishnan *et al.,* 2008; Oguntade *et al.,* 2015).

Amaranthus is an important leafy vegetable in human diet. It is a rich source of vitamins, minerals and fibers with antioxidant properties. Growing vegetables with contaminated water can lead to accumulation of genotoxic compounds in plant tissues (Mathur, 2006) and could constitute health risk to man. The extent of accumulation of toxic metals and their chemical forms in plant tissues has been reported to determine their potential health risk (Zayed *et al.,* 1998; Saggoo and Grewal, 2003). Dye effluent pollution of stream and rivers used by farmers for dry season production of vegetables in Abeokuta has constituted an environmental health challenge that requires attention. Hence this study is aimed at assessing the impact of dye industrial effluents irrigation on heavy metal uptake by potted amaranthus. Also to determine contribution of the dye effluents to soil heavy metal load in the potted soil on which the amaranthus was grown.

MATERIALS AND METHODS

Dye effluents collected at discharge points from three local dyeing industries (Asero, Itoku and Kemta) in Abeokuta were applied at four rates (0 %, 25 %, 50 %, 100 %). The 36 treatments were applied to 5 kg potted soil arranged in a Completely Randomized Design (CRD) and replicated three times. The untreated dye effluents diluted with fresh water in four rates was applied as irrigation water. The rate was to simulate the practice of farmers who used dye polluted stream water for vegetable production in the study area. Amaranthus (*Amaranthus cruentus* L.) seed were then sown in the potted soils and watered three times for the first week of planting. This was done to allow seed emergence before application of treatments and to prevent possible phytotoxicity of the effluent. Thereafter amaranthus seedlings were irrigated with 200 ml of the different concentrations of the dye effluents three times in a week for another five weeks. Treatment with dye concentrations of 100 % from the three sources and 50 % concentration from Kemta was suspended following death of amaranthus seedlings after the first and second doses of dye effluent irrigation, respectively.

Surviving seedlings of amaranthus were thinned to one plant per pot at two weeks after planting (WAP). At six weeks after planting the amaranthus was harvested. Above soil biomass of amaranthus was harvested as edible shoot. Root were then carefully dug out from the pot and washed off any soil particles. The plant parts were later oven-dried at 60 ^{0}C to constant weight and the oven-dried weight was determined. The dry plant samples were ground with pestle and mortar for laboratory analysis.

Analyses of heavy metals in amaranthus tissues and soil

Earlier grounded plant sample was digested using nitric acid and perchloric acid (2:1) for 1 hour 30 minutes by weighing 0.5 g of samples in digestion tube. The temperature of the digest was raised to 230 ^{0}C following addition of 2 ml of HCl and distilled water. The mixture was then further digested for another 30 minutes. Thereafter, the clear digests were allowed to cool and rinsed into 50 ml volumetric flask and made up to mark with distilled water. The heavy metal concentration of the digests was then determined on Buck Scientific 210 VGP model Atomic Absorption Spectrophotometer (AAS). Concentrations of Fe, Mn, Cu, Zn, & Cr in potted soils were also determined (Udo *et al.,* 2009).

Data analysis

Data collected were analyzed using SAS procedure (SAS 1998). Significant treatment means were separated by Duncan's Multiple Range Test (DMRT) at 5 % probability level.

RESULTS AND DISCUSSION

Effects of dye effluents on heavy metal uptake by amaranth

In Table 1 the varying concentrations of dye effluent significantly ($p < 0.05$) increased heavy metal uptake in both amaranthus shoot and root. The effluent from the three sources showed increased heavy metals accumulation in amaranthus tissues compared with fresh water irrigation. Heavy metal uptake and accumulation in amaranthus root and its subsequent translocation to shoot was higher with 25 % than 50 % concentration particularly with Asero and Itoku effluents. The lower uptake of heavy metals at 50 % dye concentration than at lower rate of 25 % could be due to toxicity or adverse effects of higher concentration of dye effluent on the root cells which impaired its tissues which is the contact organ leading to lower uptake of metals (Farooq *et al.,* 2008; Yousaf *et al.,* 2010; Oguntade *et al.,* 2015). At 25 % concentration of dye effluent from Itoku, the Fe and Zn uptake in edible shoot of amaranthus were higher than 0.30 mg kg^{-1} allowable limits by World Health Organization/Food and Agricultural Organization (2001) and Federal Environmental Protection Agency (1991) in vegetables. Application of 50 % of Kemta dye effluent and 100 % of dye effluent from the three sources caused death of the amaranthus. This is due to phytotoxicity of higher concentration of dye effluent on the amaranthus.

Effects of dye effluent on heavy metal accumulation in the soil

Dye effluents collected from the three dyeing sites showed differential effects on heavy metal

Table 1: Metal ion uptake (mg $plant^{-1}$) by *Amaranthus cruentus* L. shoot and root irrigated with dye effluents in pot culture

Effluent sources	Concentration (%)	Mn		Fe		Cu		Zn		Cr	
		Shoot	Root	Shoot	Root	Shoot	Root	Shoot	Root	Shoot	Root
	0	0.05ab	0.0020a	0.11b	0.0212a	0.008b	0.0009a	0.04a	0.0037ab	0.0006b	0.001a
	25	0.14a	0.0029a	0.20a	0.0316a	0.016a	0.0013a	0.07a	0.0066a	0.0010a	0.002a
Asero	50	0.07ab	0.0025a	0.16ab	0.0280a	0.013ab	0.0012a	0.06a	0.0040ab	0.0010a	0.002a
	100	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
	0	0.06b	0.0018a	0.12b	0.0179a	0.008ab	0.0006b	0.05c	0.0024b	0.0005b	0.001b
	25	0.14a	0.0038a	0.32a	0.0282a	0.017a	0.0013a	0.31a	0.0074a	0.0011a	0.002a
Itoku	50	0.09b	0.0026a	0.17b	0.0250a	0.012ab	0.0012ab	0.16b	0.0046ab	0.0010a	0.002a
	100	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
	0	0.05b	0.0029b	0.10b	0.0339b	0.002b	0.0014b	0.04b	0.0033b	0.001b	0.001b
	25	0.12a	0.0070a	0.19a	0.0688a	0.010a	0.0042a	0.08a	0.0087a	0.001a	0.002a
Kemta	50	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
	100	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd

nd = no data due to death of plants, Means in the same column followed by the same letters are not significantly different ($p \leq 0.05$) according to Duncan's Multiple Range Test

Table 2: Effects of dye effluents on means concentrations of metal ions of potted soil

Effluent Sources	Mn	Fe	Cu	Zn	Cr
	mg kg^{-1}				
Control	7.12b	27.94c	0.17b	1.19c	3.33b
Asero	12.26a	41.41b	0.34a	3.00a	6.11a
Itoku	11.19a	76.71a	0.33a	1.99b	5.32a
Kemta	11.01a	76.57a	0.28a	1.62b	5.48a

Means in the same column followed by the same letters are not significantly different ($p \leq 0.05$) according to Duncan's Multiple Range Test

contents in soils that received them as sources of irrigation. Generally, all the dye effluent raised soil heavy metal levels significantly compared with fresh water irrigation. Higher concentration of Mn accumulated in soil that received Asero dye effluent than Itoku and least in Kemta effluent (Table 2). The effects of Itoku and Kemta dye effluents were not different from each other in terms of Fe which accumulated in the soil but were significantly higher ($p < 0.05$) than Fe which accumulated in soil irrigated with Asero dye effluent. With respect to Zn accumulation in the soil, the three sources were in order of Asero > Itoku > Kemta. With Asero effluent having significant higher effects on soil Zn over the other two sources. The significant elevated amount of soil Fe with dye effluents from Itoku and Kemta as well as soil Zn with Asero effluent could be due to high levels of these metals in the various compositions of the effluents. The amount of Cu and Cr which accumulated in the soil after irrigation with dye effluent from the three sources were not significantly different from each other. However, soil Cu accumulation was in the order of Asero > Itoku > Kemta while soil Cr accumulation trend was in the order of Asero > Kemta > Itoku dye effluents. The significant accumulation of these metals in soil irrigated with dye effluents over fresh water irrigation indicated that the untreated dye effluent contained substantial amount of heavy metal (Oguntade *et al.*, 2013).

CONCLUSION

It can be inferred from this study that Amaranthus can uptake significant amount of heavy metals from soil when grown in heavy metal contaminated medium. However, higher concentration of untreated dye industrial effluent could be injurious to amaranthus seedlings leading to lower heavy metal uptake and consequently death. In exploiting nutrient potentials in dye effluent, there is need for proper treatment or at least proper dilution to about 90 % concentration before irrigation. This may prevent possible build up of toxic metals in the biosphere and food chain.

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