

Heavy Metal Accumulation and Arthropod Abundance in Leafy Vegetable Cultivation

Joseph C. Anikwe
Entomology Unit, Department of Zoology, Faculty of Science, University of Lagos, Akoka, Lagos, Nigeria;
jachuks@yahoo.com

Abstract
Heavy metal contamination of soils used for crop cultivation constitutes danger to biodiversity conservation and environmental health. This study therefore investigated heavy metal accumulation in soils used for vegetable cultivation and their effects on the diversity and abundance of arthropods. Analysis of soil samples collected from selected plots used for leafy vegetable cultivation viz; *Corchorus olitorius* L. (Tiliaceae), *Amaranthus hybridus* (Amaranthaceae) and *Celosia argentea* (Amaranthaceae) showed different levels of heavy metal contamination. Insect abundance and diversity from each vegetable plant was also recorded. Zinc was the most accumulated with concentrations ranging from 3.06 mg/kg to 4.99 mg/kg. Copper was next with concentration ranging from 0.71 mg/kg to 0.95 mg/kg in the soil. Cadmium was the least accumulated of all the heavy metals in soils from the three vegetable sites. A total of 22 different insect species were recorded at different physiological growths of leafy vegetables at the study area in 2011/2012 cropping seasons. *Hymenia recurvalis* was the most abundant insect pest species ranging from 34.86 in *A. hybridus* to 16.96 in *C. Olitorius* in 2011. The insect pests' incidence had a similar trend for both years. The concentration of heavy metals from this study did not exceed safe limits, hence there was a fair abundance and diversity of insects found on the leafy vegetables.

Key words: heavy metals, accumulation, arthropod abundance, insect diversity, Leafy vegetables.

Introduction

Vegetable production has become a profitable enterprise and very popular in Nigeria. They are either cultivated for their edible fruits or nutritional leaves (Omoloye & Ajani 2009). However in recent times, the harsh economic downturn has made many people who otherwise would not engage in farming to take to vegetable production either as full time occupation due to retrenchment or forced retirement or as a part-time activity in order to augment household earnings. This has led to an unprecedented increase in the utilization of all lands available within the metropolitan areas of the southwest particularly in Lagos, Ogun and Oyo States for agricultural and horticultural purposes (Omoloye & Ajani 2009).

The commonest sources of contamination of urban agricultural soils especially in the southwest Nigeria are deposition of wastes of domestic, municipal and industrial origin as well as agrochemical contaminants on open dumps sites which decompose resulting to undegradable contaminants (Margaret 1998; Simon *et al.* 2011). Heavy metals such as lead, mercury and cadmium have been implicated by the World Health Organization (WHO) as primary causes of cancer, natural mortality, livestock health problems, serious human health problems and nerve damage (Coyer 1971, Ananda 1976). It is most probable that majority of these urban agricultural sites are heavily contaminated with heavy metals due to nearness to industrial wastes, automobile emissions and factory effluents (Glenn *et al.* 1993). These heavy metals are toxic to man and livestock when present in diets beyond certain limits as established by codex alimentarius (Glenn *et al.* 1993, Ogunyemi *et al.* 2003). In terms of heavy metal contamination, the safety of these vegetables from urban garden farm is of utmost concern (Ogunyemi *et al*. 2003). In agricultural ecosystems, where animal farming and related agricultural practices are intensive, heavy metals can reach the soil due to the application of commercial fertilizers, sewage sludge and pesticides, which may usually contain a wide variation of heavy metals as impurities (Nicholson *et al.* 2003). Therefore, soil can behave as a sink for heavy metals resulting from agricultural practices (Franco-Uria *et al.* 2008). Also, as advantageous as organic matter such as poultry droppings are to vegetable production by serving as a source of nitrogen, phosphorous and sulphur, it however has a binding capacity for cations and organic contaminants (Oste *et al.* 2002). Heavy metals have been found to accumulate in surface organic layers in agricultural and urban soils (Dragovic *et al.* 2008).

This study therefore investigated the level of heavy metal accumulation in intensively pesticide-used agricultural soils and their effects on the abundance of insect species of three leafy vegetables in Lagos State.

MATERIALS AND METHODS

Study site: The study site where the soil samples were collected for heavy metal contamination was Odogunyan in Ikorodu, Lagos State. It is located within the geographic coordinates of $6^o39'23''$N and $3^o31'29''$E. The agricultural farmland in Odogunyan was initially owned by the government but was allocated to private individuals as far back as the 60's for vegetable cultivation. The farmers rely heavily on the use of organic manure (poultry droppings) and pesticides to enhance productivity. The major leafy vegetables cultivated in monocropping systems were *Corchorus olitorius* L. (Tiliaceae), *Amaranthus hybridus* (Amaranthaceae) and *Celosia argentea* (Amaranthaceae).

Soil sample collection: A Dutch auger with graduated markings to allow the determination of penetration depth was use for the collection of soil samples. Fifteen soil samples were randomly collected, five each from each mono-cropped leafy vegetable plots of 2 ha, located at Odogunyan were collected from the depth of 0-15cm. The soil samples were put into black polythene bags and properly labelled. The soil samples were then digested following the method of AOAC (1984). The digested samples were analysed for heavy metal using the Atomic Absorption Spectrometer (AAS) following the method described by AOAC (1984). A 1g sample of soil was weighed into a conical flask to which 10ml perchloric acid and atomic acid in ratio 1:5 was added. The mixture was heated gently to avoid frothing after which the temperature was increased till clear white fume was emitted. The digested sample was washed into 5ml flask and made up to mark with de-ionised water. The heavy metals (copper, zinc, nickel, cadmium, lead and chromium) were detected by aspiration on the Atomic Absorption Spectrometer. The physico-chemical parameters of soil samples were also analysed.

Insect samplings: The insect populations from the three different vegetable plots were sampled very early in the morning when the insects were less active throughout the study period, commencing from one week after planting (WAP). The samples were collected on diagonal lines in each plot on 30 randomly selected plants and three leaves were selected randomly, one each from the top, middle and bottom parts of the plant. The numbers of insects on the vegetable plants were recorded using direct method to enable for quantitative estimation of insect incidence on the leafy vegetables. Flying insects were also collected non-discretely using sweep net over each vegetation cover along a transect and fast flying insects were counted insitu using tally counter in all the experimental plots.

All data collected were subjected to analysis of variance (ANOVA) and mean separation was done using the Turkey Honestly Significant Difference test (Turkey HSD) at 5% level of probability (SAS, 1999).

RESULTS

Soil analysis: The result of the physico-chemical parameters of soil samples is presented in Table 1. The soil $_{P}$H for the three stations was slightly acidic with a range of 6.56 to 6.77 (Table 1). The various parameters measured were soil moisture, organic matter, total organic carbon and soil $_{P}$H. These were not significantly different ($P>0.05$) across all three vegetable stations (Table 1). The level of contamination of the vegetable stations by heavy metals did not also vary significantly ($P<0.05$) in all soil samples (Table 2). Zinc was the most accumulated with concentrations ranging from 3.06 mg/kg to 4.99 mg/kg. Copper was next with concentration ranging from 0.71 mg/kg to 0.95 mg/kg in the soil. Cadmium was the least accumulated of all the heavy metals in soils from the three vegetable sites. These concentrations were significantly lower than the maximum tolerable limit for heavy metals in the soil (Codex FAO, 1996).

Insect abundance: A total of 22 different insect species were recorded at different physiological growths of the leafy vegetables at the study area in 2011 and 2012 cropping seasons (Tables 3 and 4). Among the insect pests, *Hymenia recurvalis* was the most preponderant ranging from 34.86 in *A. hybridus* to 16.96 in *C. Olitorius* in 2011 and a mean value of 16.35 at week 3 on Amaranth in 2012. This was closely followed by *Aphis gossypii* which was even distributed on all three leafy vegetables from one to three weeks after planting (Table 3). *Podagrica uniforma* and *P. sjostedti* were present in all vegetables sampled with higher mean populations of 3.85 and 4.75, respectively in 2011 on *C. Olitorius* whereas *C. argentea* had the least mean populations of insect pests on it at the third week (Table 3). Some insect pests such as *Psara bipunctalis, Logria species* and *Alaucophora species* were not recorded on Celosia in 2011 and a similar trend was recorded for *Logria species* and *Alaucophora species* in 2012 (Table 4).

Ant species encountered were not herbivores but rather natural enemies. *Camponotus* was the most abundant of the natural enemies with the highest mean population record of 38.14 on Celosia. *Oecophylla longinoda* was found attracted to honeydew secretion from Aphids and therefore found on all the three leafy vegetables tending *A. gossypii.* The species of *Epilachna* beetle recorded on the leafy vegetables was not phytopagous.

DISCUSSION

Soil analysis: Organic matter content, pH and bioavailability of heavy metals are critical factors for the heavy metal accumulation in soils (Oste *et al.* 2001). Van Gestel *et al.* (1997) reported that increase in organic matter, increased Zn concentrations in the soil. High concentration of Zn recorded in all the soil samples in the study area could be as a result of the application of poultry dough which invariably increased the organic matter of the soil. Also, the coexistence of heavy metals such as Pb and Cd in the sampled stations has a lot of environmental implication. When heavy metals coexist in the environment, it is important to confirm the exact interaction among these metals because it will significantly affect their bioaccumulation processes in organisms and toxicologically effects on different biological levels (Wu *et al.* 2012).

Effects of heavy metals on insect species: A major observation at the vegetable cultivation in Ikorodu was the intensive used of agricultural inputs such as fertilizers and pesticides which inadvertently led to accumulation of heavy metals in the soil. This assertion is in consonance with Mico *et al.* (2006) and Franco-Uria *et al.* (2009) who affirm that the main source of Cd in agricultural soils is the use of various fertilizers and pesticides. Cadmium is found predominantly in phosphatic fertilizers because it is commonly present as impurity in phosphatic rocks while Zn and its compounds are widely used in agricultural fertilizers and cattle slurry. It is well known that the occurrence of heavy metals directly affected the abundance of insect species in vegetables (Omoloye & Ajani 2009). However, in this study the distribution of insects encountered as well as the abundance of each species was not quite different from the array of arthropods found on leafy vegetables (Okunlola *et al.* 2008, Omoloye & Ajani 2009). The concentration of heavy metals from this study did not exceed safe limits and there were diverse occurrences as well as abundance of arthropod species on the three leafy vegetables.

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Table 1: Mean values of soil physico-chemical properties from the three selected stations

Stations	% Moisture	P^H	% Organic matter	% Total Organic Carbon
Amaranthus hybridus soil	12.16a	6.56a	4.60a	1.33a
Celosia argentea soil	13.24a	6.77a	5.20a	1.15a
Corchorus olitorius soil	11.95a	6.75a	4.88a	1.24a

Values followed by the same letter within a column are not significantly different (Tukey HSD, p=0.05)

Table 2: Heavy metal accumulation in leafy vegetable cultivated soils in Ikorodu, Lagos

Stations/ Soil	Cu	Zn	Ni	Cd	Pb	Cr (mg/kg)
Amaranthus hybridus	0.71a	4.99a	0.33a	0.18a	0.40a	1.02a
Celosia argentea	0.95a	3.06a	0.31a	0.17a	0.44a	0.97a
Corchorus olitorius	0.84a	4.15a	0.35a	0.15a	0.41a	1.05a

Values followed by the same letter within a column are not significantly different (Tukey HSD, p=0.05)

Table 3: Mean number of arthropods population found on leafy vegetables in Ikorodu, Lagos in 2011 cropping season

Major arthropods encountered	Plants and Weeks After Planting								
	Amaranthus hybridus			*Celosia argentea*			*Corchorus olitorius*		
	1	2	3	1	2	3	1	2	3
Hymenia recurvalis	16.75	34.86	27.38	0.1	8.11	4.75	11.75	16.96	8.85
Aphis gossypii	15.13	21.45	8.55	12.24	18.46	4.76	11.12	15.05	4.85
Dsydercus superstiotus	2.45	3.74	3.56	2.04	2.86	2.6	2.67	2.35	3.01
Psara bipunctalis	0.25	2.14	3.75	0	0	0	1.34	0.97	1.25
Ootheca mutabilis	0.15	1.97	2.43	0	0.12	2.87	0.95	2.98	3.41
Podagrica uniforma	1.17	1.36	1.33	1.56	1.44	1.23	2.16	2.27	3.85
Podagrica sjostedti	2.22	2.19	2.34	1.45	1.17	1.24	3.45	4.17	4.75
Nezara viridula	0	0.05	0.19	0	0.11	0.15	0	0.06	0.15
Zonocerus variegatus	2.76	2.32	2.65	1.57	1.94	1.89	2.35	2.47	2.91
Logria species	0	0	0	0	0	0	0.56	0.08	0.12
Lixus species	0.65	0.1	0.24	0	0	0.32	0.78	0.65	0.84
Alaucophora species	0	0.26	0.14	0	0	0	0	0	0.31
Gasterodisus rhomboidalis	0	0.12	0.45	0.32	0.16	0.19	0.12	0.17	0.25
Sylepta derogata	0.65	0.77	1.94	1.22	1.43	1.77	1.85	2.92	2.98
Aspavia armigera	1.07	1.99	2.04	1.01	1.02	1.25	1.37	2.05	2.76
Helopeltis schoutedni	0.66	0.67	2.02	1.11	1.34	2.03	1.96	2.29	2.18
Acraea eponina	0.21	0.65	0.65	0.09	0.23	0	0.56	0.08	0.12
Diopsis thoracica	0.02	0.07	0.21	0.03	0.14	0.17	0.04	0.08	0.15
Crematogaster brevispinosa	8.54	6.49	6.26	7.22	6.97	8.05	6.78	6.32	7.01
Oecophylla longinoda	4.45	5.57	5.56	4.04	4.88	4.78	4.67	5.35	6.09
Camponotus species	21.17	27.84	35.05	31.46	34.71	38.14	30.29	31.22	33.67
Epilachna species	4.23	4.25	3.89	3.26	3.12	3.65	4.45	4.01	4.22

Table 4: Mean number of arthropods population found on leafy vegetables in Ikorodu, Lagos in 2012 cropping season

Major arthropods encountered	Plants and Weeks After Planting								
	Amaranthus hybridus			*Celosia argentea*			*Corchorus olitorius*		
	1	2	3	1	2	3	1	2	3
Hymenia recurvalis	11.05	15.02	16.35	0.25	5.46	6.21	3.88	9.05	10.24
Aphis gossypii	13.27	14.44	5.06	10.11	10.57	4.11	9.34	11.01	3.88
Dsydercus superstiotus	3.12	4.58	4.77	4.01	4.45	4.24	3.11	3.95	3.56
Psara bipunctalis	0	1.25	2.96	0	1.00	1.15	0	0	0.20
Ootheca mutabilis	0.08	0.88	1.20	0.11	0.56	0.26	0.05	0.41	0.05
Podagrica uniforma	0.45	1.11	1.42	0.38	0.98	1.04	3.66	3.98	4.14
Podagrica sjostedti	1.34	1.54	1.50	1.01	1.28	1.77	3.76	3.90	4.24
Nezara viridula	0	0.56	0.21	0	0	0.08	0	0.02	0.18
Zonocerus variegatus	2.12	1.78	2.05	1.40	1.52	1.69	1.29	2.02	2.16
Logria species	0	0	0	0	0	0	0	0.05	0.05
Lixus species	0	0.06	0.18	0	0	0.09	0.01	0.14	0.17
Alaucophora species	0	0	0	0	0	0	0	0	0
Gasterodisus rhomboidalis	0	0.01	0.25	0.12	0.11	0.20	0	0.05	0.12
Sylepta derogata	0.23	0.45	1.16	1.07	1.98	2.06	0.76	1.86	2.16
Aspavia armigera	1.35	1.67	1.88	1.05	1.45	1.67	1.82	2.17	2.44
Helopeltis schoutedni	0.11	0.18	1.34	0.95	1.12	1.64	1.43	1.89	2.01
Acraea eponina	0.40	0.45	1.05	0.15	0.18	0.22	0.44	0.98	0.87
Diopsis thoracica	0	0	0.15	0	0.11	0.15	0.06	0.16	0.28
Crematogaster brevispinosa	7.64	7.58	7.84	6.85	6.98	7.42	7.66	7.49	8.10
Oecophylla longinoda	6.11	6.52	6.88	6.99	6.86	6.48	6.83	7.12	7.65
Camponotus species	32.32	29.62	31.26	32.24	32.78	34.28	33.05	34.64	34.09
Epilachna species	2.15	1.96	2.01	1.84	2.45	2.17	2.22	2.62	2.06