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Metal bioaccumulation in some Auchenorrhyncha (Hemiptera) species in apple orchards

Murat KARAVIN[1]

[1] Suluova Vocational School, Amasya University, Suluova, Amasya, Turkiye

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Corresponding Author: Murat KARAVIN
E-mail: murat.karavin@amasya.edu.tr

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Abstract
Traffic is an important pollution factor causing environmental damages such as soil, water and atmospheric pollution, greenhouse effect, and climate change. Effects of traffic pollution on various organisms enlightened with various studies. In this study, it was aimed to examine the effects of traffic-based pollution on Auchenorrhyncha (Insecta: Hemiptera) species in apple orchards and their potential as biomonitor for heavy metal pollution. The Auchenorrhyncha specimens were collected from the apple orchards near the Amasya-Samsun motorway in Türkiye. The heavy metal concentrations were determined by ICP-OES. Five Auchenorrhyncha species were determined from three sites from each of three different distance. *Empoasca decipiens* specimens were collected only from 0 m while others found in all localities. Heavy metal concentrations in insect specimens tended to decrease with the increasing distance from the motorway. These differences were clearly indicated in *Psammotettix provincialis* and *Phlepsius intricatus*, which were found in all localities. Except for Ni, Fe and Mn for *Phlepsius intricatus,* all examined heavy metals significantly varied in both species. Results showed that heavy metals tended to accumulate in the body of Auchenorrhyncha specimens and because of this they may be evaluated as a biomonitor for heavy metal pollution.

Keywords: Auchenorrhynca, Apple orchard, Metal, Insect, Air pollution, Bioindicators

INTRODUCTION

Traffic is an important pollution factor in terrestrial ecosystems. Traffic-based pollutants tend to accumulate on the surface and tissues of organisms, causing metabolic changes and damages. Additionally, dispersal and diversity of organisms are also affected by pollution factors. Previous studies presented a negative effect of motorways on some groups of animals (Trombulak and Frissell, 2000; Forman et al., 2003; Muñoz et al., 2015). Traffic-related pollutants such as HC, CO, NOx, PM, SO_2 and heavy metals may change the nutrient status of plants and affect herbivore feeding indirectly. Although there are several studies on effects of traffic-based pollution on organisms, still there is a little knowledge about insects.

In general, traffic pollution affects insects by two ways (external environmental pollution and through contaminated foods). It is known that insects usually feed on plants and traffic pollution have an important impact on plants. Previous studies reported that impacts of pollution on plant-feeding insects may be in three types (1) affecting habitat quality, (2) plant quality, or (3) the life of natural enemies (Zvereva and Kozlov, 2006; Butler and Trumble, 2008).

In the literature, studies about the effect of traffic pollution on insects were usually carried on aphids because of ease of collection and feeding monophagous on plants (Devkota and Schmidt, 2000; Viskari et al., 2000; Boyd, 2009). Other studies focused on Aranea, Coleoptera Odonata, Lepidoptera and Hymenoptera (Samways et al., 1997; Severns, 2008; Hayward et al., 2010; Melis et al., 2010; Soluk et al., 2011). Karavin (2024) investigated the heavy metal concentrations accumulated in the bodies of Auchenorrhyncha species depending on the distance from the road in cherry orchards and found that the heavy metal concentrations in the specimens increased as the distance from the motorway decreased.

In the case of aphids, it was observed that plants exposed to air pollutants were usually preferable hosts. For example, it was found that aphids feeding on plants exposed to traffic pollutants exhibited higher relative growth rates and population density (Dohmen et al., 1984; Warrington et al., 1987; Houlden et al., 1990; Heliövaara and Vaisanen, 1993; Summers et al., 1994; Gao et al., 2008). Furthermore, the effects of metal pollution on the immune system of ants and night butterflies were studies by Sorvari et al. (2007) and van Ooik et al. (2008). A study on usage of insects as bioindicators for metal pollution were carried out by Nummelin et al. (2007). Negative effects were reported in weight, growth, survival, reproduction and hatching success for insects due to heavy metal pollution in the previous studies (Boyd and Martens, 1998; Kramarz and Stark, 2003; Scheirs et al., 2006; Noret et al., 2007; van Ooik et al., 2008; Butler and Trumble, 2008).

Some of the predatory insects, which can accumulate high amounts of metals in their bodies can be used as bioindicators for the environments (Nummelin et al., 2007; Riaz et al., 2023). Proper usages of insects as bioindicators for heavy metal pollution were indicated with the previous studies (Parikh et al., 2021; Adelanwa et al., 2016; Girotti et al., 2020; Riaz et al., 2023). Adelanwa et al. (2016) reported that *Salvinia molesta* is a good phytomediator for copper (Cu) and lead (PB) (Riaz et al., 2023).

Because of their morphological characteristics, high reproduction rate, and great mobility range, butterflies, spiders and honeybees are used as biomonitors for environmental pollution (Girotti et al., 2020; Murashova et al., 2020; Riaz et al., 2023).

This study aimed to determine the impacts of traffic pollution on bioaccumulation of heavy metals in Auchenorrhyncha species in apple orchards and their potential as biomonitor for heavy metal pollution. Auchenorrhyncha species can have impacts on plants by feeding and, in some cases, transmitting plant pathogens. Some of them are important pests for economically important plants (Guglielmino, 2000; Rizwan et al., 2020). Because the Auchenorrhyncha species have various niches in urban, agricultural land and forestland. Therefore, assessing their role of bioindicator of heavy metal could be important because they can be found in very different environments.

MATERIALS AND METHODS

The study was carried out in apple orchards near the motorway in Amasya (40°45′17.3″N 35°44′00.7″E), Türkiye. Sweeping nets were used to collect Auchenorrhyncha specimens. Samplings were performed in three sites from each of three different distances from the motorway, 0 m, 50 m, 100 m in the apple orchards. Before preparation, the samples were kept in 5% acetic acid solution. Specimens were examined in detail under stereo-microscope. Genital parts of the specimens were removed with the help of a dissection needle. Species were identified by comparing with the descriptions and figures given in Ribaut (1936), Kalkandelen (1974), Ossiannilsson (1981) and Holzinger et al. (2003).

In order to determine the heavy metal contents of specimens, microwave extraction method was applied to dried and milled specimens (Naccarato et al., 2020; Karavin, 2024). Heavy metal contents were measured by using ICP-OES as mg.kg -1 dry weight. SPSS 20 was used for statistical analyses. Normality tests were performed for data set and homogeneity of variance was tested by the Levene's test. One-way ANOVA (analysis of variance) was used to compare the means. Differences between the means were analyzed with the Tukey test when the variances were homogeneous, and with the Welch test where they were not homogeneous.

RESULTS AND DISCUSSION

Five Auchenorrhyncha species: *Empoasca decipiens* Paoli, 1930; *Laodelphax striatella* (Fallén, 1826); *Arboridia versuta* (Melichar, 1897); *Psammotettix provincialis* (Ribaut, 1925) and *Phlepsius intricatus* (Herrich-Schaffer, 1838) were identified in the apple (*Malus domestica* Borkh.) orchards and examined for heavy metal bioaccumulation (Table 1). *E. decipiens* specimens were collected only from 0 m while other species found in all sites.

According to the results, there was a decreasing trend in the heavy metal concentrations in Auchenorrhyncha species in apple orchards with the increasing distance from the motorway and it is suggest that likely this is due to the traffic pollution. The maximum heavy metal concentrations were determined in *A. versuta* while the minimum values were measured in *P. provincialis* and *P. intricatus*. The average heavy metal concentrations determined in the examined species are compatible with the literatüre. The heavy metal concentrations of the specimens collected in this study were similar to the values determined in apple leaves by Karavin and Ural (2016). Karavin and Ural (2016) reported same decreasing trend in the heavy metal concentrations in the apple leaves with the increasing distance from the motorway.

Because *P. provincialis* and *P. intricatus* were collected from more than one plots in all sites, the variations in the heavy metal concentrations in specimens due to distance from the motorway were indicated for them (Figure 1, 2). Except nickel (Ni), iron (Fe) and manganese (Mn) for *P. intricatus*, all the examined heavy metals were significantly varied in both species.

Similar decreasing trends in the heavy metal concentrations in *A. versuta, P. intricatus, L. striatella* and *P. provincialis* in the cherry orchards with the increasing distance from the motorway were also found in the study of Karavin (2024). *E. decipiens* could only be collected at 0 m in the apple orchards, similarly, it was found more commonly at 0 m, and in only one plot at 50 m in cherry orchards. However, none were collected at 100 m in either orchard. Therefore, these results suggest that *E. decipiens* may prefer areas closer to the roadsides in both orchards.

Most Auchenorrhyncha species feed on plant sap, so they directly absorb the heavy metals found in plant sap. Cadmiun (Cd), zinc (Zn), copper (Cu), arsenic (As), Fe, mercury (Hg) and lead (Pb) are usually reported in superworms, yellow mealworms, termites, locusts, black soldier fly larvae and grasshoppers (Malematja et al., 2023). In some previous studies conducted with grasshoppers, heavy metals such as Pb and Cd were found in insect bodies (Handley et al., 2007; Zhang et al., 2009; Poma et al., 2017).

It has been reported that the amount of heavy metals in some insects used as food, such as grasshoppers, ants and locusts, are above the levels recommended by the World Health Organization (Muhammad et al., 2022). As in soil and plants, the heavy metal with the highest concentration in the examined Auchenorrhyncha species is Fe. Similarly, Denloye et al. (2015) and Mézes (2018) reported high concentrations of Fe in termites, grasshoppers and locusts. Azam et al. (2015) reported that the most accumulated heavy metal in insect species such as *Crocothemi servilia*, *Oxya hyla hyla* and *Danaus chrysippus* was Cd and it was followed by Cu, Chromium (Cr) and Ni, respectively (Riaz et al., 2023). It was explained that heavy metal concentrations in insects varied in accordance with the pollution level of the area. It was reported that Cu concentration in worker termites found in southwestern Nigeria was 0.076 mg/L (Idowu et al., 2019), in termites collected from natural habitats was 0.08-0.18 mg/L (Kapaale et al., 2021) and in housefly larvae was 9.06 mg/kg (Gao et al., 2019). The accumulation of heavy metals in insects varies depending on the pollution status in the habitat, insect species and heavy metal type (Ng'ang'a et al., 2021; Malematja et al., 2023).

According to the results of the study, the number of species did not vary according to the distance from the motorway. This means that traffic-related pollution did not have a deterrent effect on the species in apple orchards established close to the motorway. However, the high accumulation of heavy metals in specimens collected from the plots near the motorway suggested that there may be heavy metal contamination in apples grown close to the motorway. In fact, in the study conducted by Karavin and Ural (2016) in apple orchards, it was found that the concentration of heavy metals in apple leaves was higher in the plots near the motorway. The findings of both studies showed that for plant and human health, fruit orchards should be established in the areas far from the motorways to avoid heavy metals.

CONCLUSION

Although there is also metal pollution in agricultural lands caused by pesticides, fertilizer applications, vehicles and tools which are used in agricultural activities, the results obtained in this study reflect the effects of traffic pollution since sampling was done according to the distance from the highway and heavy metal concentrations were evaluated according to the distance from the highway. Results clearly indicates significant variations in heavy metal concentrations in the specimens based on traffic pollution. Decreasing trends were determined in the heavy metal concentrations in Auchenorrhyncha species in apple orchards with the increasing distance from the motorway and it is suggest that likely this is due to the traffic pollution. Results of this study showed that heavy metals tended to accumulate in the body of Auchenorrhyncha specimens and because of this they may be evaluated as a biomonitor for heavy metal pollution, especially *A. versuta*. It is thought that similar studies to be conducted in different areas are needed to clearly reveal the heavy metal accumulation in Auchenorrhyncha species due to pollution and the use of these species as biomonitors.

Table 1. Means metal concentrations in specimens.

Empoasca decipiens			**Metals (mg.kg^{-1} ± SD)**							
m	Plot	n	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb
0	1	21	0.59 ±0.0002	1.23 ±0.0008	0.37 ±0.0017	2.69 ±0.0052	8.24 ±0.0013	0.56 ±0.0013	0.08 ±0.0022	3.19 ±0.0025
	2	8	2.84 ±0.0071	4.88 ±0.0236	2.28 ±0.0326	10.72 ±0.0759	63.92 ±0.5116	1.32 ±0.0015	0.44 ±0.0329	15.00 ±0.0314
	3	10	1.39 ±0.0022	2.91 ±0.0033	0.67 ±0.0016	4.32 ±0.0045	7.64 ±0.1476	0.45 ±0.0001	0.12 ±0.0190	6.64 ±0.0679
Laodelphax striatella										
0	1	9	0.81 ±0.0006	1.70 ±0.0002	0.41 ±0.0001	2.15 ±0.0071	12.59 ±0.0355	0.25 ±0.0015	0.07 ±0.0021	3.40 ±0.0039
	2	10	0.72 ±0.0002	1.47 ±0.0005	0.45 ±0.0013	2.77 ±0.0027	8.68 ±0.0293	0.48 ±0.0007	0.13 ±0.0074	4.10 ±0.0019
50	2	13	0.01 ±0.0000	0.02 ±0.0001	0.09 ±0.0002	0.87 ±0.0045	4.36 ±0.0546	0.11 ±0.0010	0.05 ±0.0018	0.73 ±0.0087
100	1	12	0.03 ±0.0009	0.05 ±0.0012	0.05 ± 0.0003	0.50 ±0.0063	2.14 ±0.0193	0.3 ±0.0025	0.18 ±0.0018	0.88 ±0.0175
	2	8	0.04 ±0.0014	0.07 ±0.0002	0.07 ±0.0008	0.61 ±0.0029	2.22 ±0.0180	0.13 ±0.0006	0.23 ±0.0007	1.21 ±0.0220
Arboridia versuta										
0	1	7	3.57 ± 0.0034	7.57 ±0.0168	2.28 ±0.0048	14.71 ±0.0245	42.46 ±0.1901	13.42 ±0.1403	0.55 ±0.0031	18.58 ±0.0336
50	1	15	0.98 ±0.0022	2.07 ±0.0043	0.69 ±0.0009	3.79 ±0.0009	14.53 ±0.0275	0.32 ±0.0004	0.10 ±0.0004	4.72 ±0.0104
	2	9	1.50 ±0.0006	3.17 ±0.0030	1.06 ±0.0008	3.41 ±0.0057	11.79 ±0.0227	0.65 ±0.0032	0.23 ±0.0075	7.23 ±0.0741
100	1	7	0.05 ±0.0019	0.16 ±0.0119	0.53 ±0.0014	4.69 ±0.0326	31.20 ±0.3935	3.36 ±0.0045	0.96 ±0.0442	4.96 ±0.0535
Psammotettix provincialis										
0	1	8	0.59 ±0.0002	1.20 ±0.0015	0.41 ±0.0026	2.59 ±0.0063	9.28 ±0.1671	0.51 ±0.0041	0.10 ±0.0072	3.33 ±0.0137
	2	7	0.57 ±0.0005	1.18 ±0.0057	0.36 ±0.0065	2.26 0.0005	7.80 ±0.1391	0.35 ±0.0051	0.08 ±0.0022	2.95 ±0.0651
	3	9	0.55 ±0.0010	1.16 ±0.0006	0.30 ±0.0007	1.91 ±0.0156	6.10 ±0.0376	0.18 ±0.0008	0.05 ±0.0010	2.55 ±0.0028
50	1	28	0.20 ±0.0004	0.42 ±0.0007	0.10 ±0.0001	0.72 ±0.0014	2.12 ±0.0304	0.12 ±0.0002	0.02 ±0.0012	0.94 ±0.0044
	2	83	0.16 ±0.0001	0.34 ±0.0001	0.08 ±0.0002	0.57 ±0.0025	1.69 ±0.0166	0.09 ±0.0008	0.02 ±0.0012	0.75 ±0.0086
	3	62	0.12 ±0.0001	0.25 ±0.0001	0.11 ±0.0001	0.50 ±0.0007	1.07 ±0.0067	0.10 ±0.0003	0.01 ±0.0005	0.56 ±0.0044
100	1	18	0.02 ±0.0004	0.030 ±0.0017	0.04 ±0.0005	0.43 ±0.0001	2.57 ±0.0043	0.39 ±0.0078	0.11 ±0.0004	0.51 ±0.0051
	2	12	0.03 ±0.0010	0.05 ±0.0016	0.06 ±0.0018	0.58 ±0.0067	4.01 ±0.0789	0.51 ±0.0121	0.20 ±0.0024	0.72 ±0.0426
Phlepsius intricatus										
0	2	7	0.31 ±0.0009	0.63 ±0.0001	0.23 ±0.0005	1.53 ±0.0086	5.34 ±0.0176	0.31 ±0.0011	0.05 ±0.0040	2.22 ±0.0111
	3	7	0.52 ±0.0001	1.11 ±0.0022	1.20 ±0.0050	2.30 ±0.0067	12.27 ±0.0482	0.90 ±0.0028	0.33 ±0.0064	2.74 ±0.0250
50	1	10	0.09 ±0.0001	0.20 ±0.0001	0.04 ±0.0001	0.39 ±0.0033	1.19 ±0.0021	0.10 ±0.0004	0.02 ±0.0003	0.44 ±0.0013
	2	21	0.01 ±0.0002	0.04 ±0.0004	0.07 ±0.0001	0.33 ±0.0001	0.83 ±0.0073	0.09 ±0.0010	0.01 ±0.0003	0.13 ±0.0011
	3	19	0.02 ±0.0001	0.05 ±0.0003	0.01 ±0.0002	0.36 ±0.0010	1.25 ±0.0097	0.16 ±0.0005	0.07 ±0.0007	0.16 ±0.0022
100	1	12	0.01 ±0.0001	0.02 ±0.0001	0.07 ±0.0001	0.18 ±0.0015	0.57 ±0.0027	0.06 ±0.0080	0.01 ±0.0005	0.10 ±0.0021
	2	7	0.01 ±0.0001	0.03 ±0.0009	0.10 ±0.0009	0.45 ±0.0021	1.86 ±0.0073	0.14 ±0.0004	0.04 ±0.0016	0.34 ±0.0125

(m: distance from motorway; Plot: Sampling plot; n= Number of specimens)

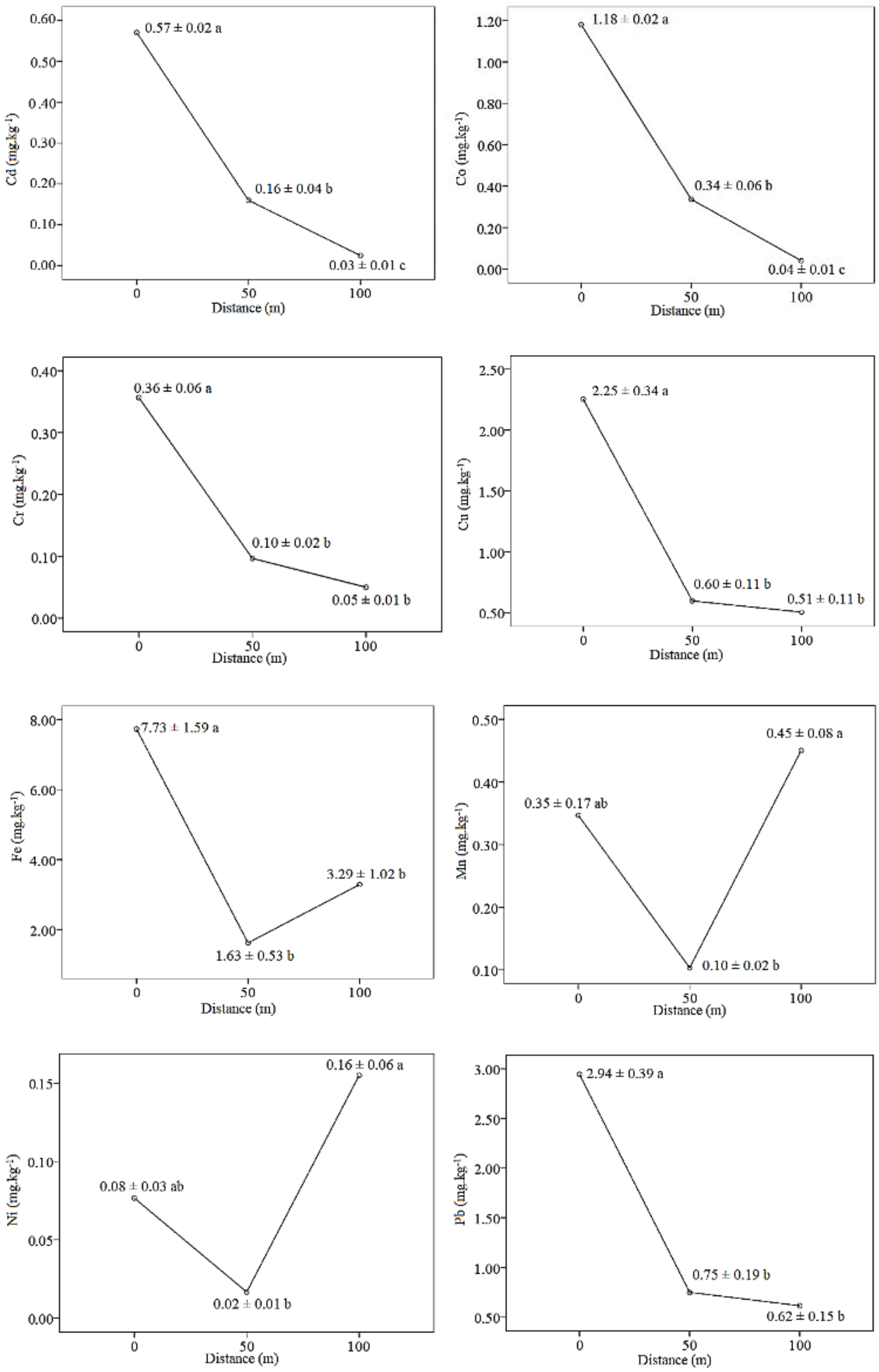

Figure 1. Metal contents of *Psammotettix provincialis* according to distance from the motorway.

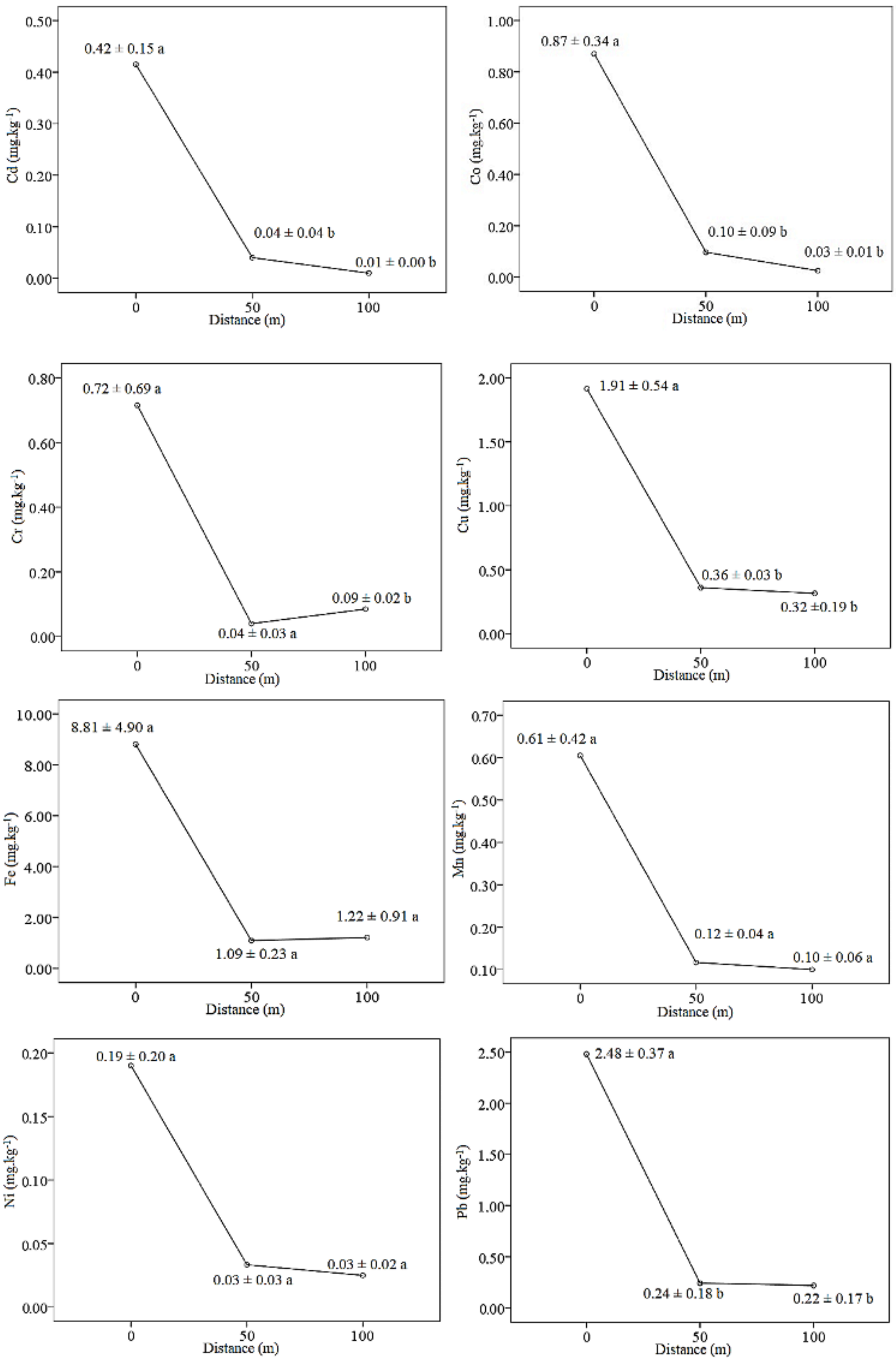

Figure 2. Metal contents of *Phlepsius intricatus* according to distance from the motorway.

Compliance with Ethical Standards

Peer-review

Externally peer-reviewed.

Conflict of interest

The author declare no competing interests.

Author contribution

The author read and approved the final manuscript. The author verifies that the text, figures, and tables are original and that they have not been published before.

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Data availability

All relevant data generated or analyzed during this study are included in this document.

Consent to participate

Not applicable.

Consent for publication

The author consent for publication.

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