EFFECTS OF HEAVY METAL ACCUMULATION IN HOST PLANTS TO CABBAGE APHID (*Brevicoryne brassicae*) – MORPHOLOGY

GAZI GÖRÜR

Nigde University, Science and Arts Faculty, Department of Biology, 51100 Nigde, Turkey
e-mail: ggorur@excite.com

Abstract

Görür G.: Effects of heavy metal accumulation in host plants to cabbage aphid (*Brevicoryne brassicae*) – Morphology. Ekológia (Bratislava), Vol. 25, No. 3, p. 314–321, 2006.

This study was carried out to search how heavy metal accumulation in host plants might affect expressions of aphid morphological traits. Accumulation of both copper (Cu) and lead (Pb) in the aphid host plants radish and cabbage, separately, had important effects on morphological traits of cabbage aphid, *Brevicoryne brassicae* L. population. All measured morphological traits of cabbage aphid become significantly smaller on host plants exposed to Cu and Pb. Results of the study clearly revealed the toxic effects of heavy metal accumulation on cabbage aphid and its subsequent adverse influences on aphid morphology.

Key words: Aphid, copper, lead, morphology

Introduction

The environment is increasingly becoming exposed to heavy metal contamination. Human activities, in different ways, have become the most important factor in global and regional heavy metal contamination (Davison et al., 1999). Heavy metal present in the soil differently accumulated in various organisms living in there and show different level of toxicity to both these organisms and others feeding on them. A clearly understanding of the effects of increased heavy metal concentration on communities requires information both on the heavy metal effects on general processes of communities and effects on the particular species. Herbivore insects-host plant relationships can be considered as model system to examine heavy metal effects. Plants can be seen as the most important route for the transfer of heavy metal from soil to herbivor insects. Aphids, in particular, are going to be affected dramatically due to their feeding style and thus they are going to be good candidate to search how herbivore insects morphology is going to be affected from heavy metal contaminated host plants features.

The potential for the accumulation of heavy metals in phytophagous insects through feeding on host plant, especially phloem feeders such as aphids has been shown in a number of laboratory, greenhouse and field studies. Merrington et al. (1997) showed a significant increase in the uptake of cadmium (Cd) and zinc (Zn) in *Rhopalosiphum padi* L. feeding on the wheat. Comparative studies on the uptake of metals by aphids are limited. Crawford et al. (1990) showed that while *Aphis fabae* S c o p. accumulating Cd in significant amount, it did not accumulate Cu. Crawford et al. (1995) demonstrated that *A. fabae* could accumulate up to 29 000 ug Cd kg^{-1} when feeding on highly contaminated host plants, but reported no negative effects of these accumulations. The grasshopper *Locusta migratoria* L. accumulated higher amount of Cu and Cd, but while that grasshopper were regulating effectively Cu, were unable to regulate Cd (Crawford et al., 1996).

Accumulation of heavy metal in plant body is going to affect both physiological and morphological features of host plant and subsequently aphid morphology. Heavy metal accumulation in organisms (aphids) might cause additional energy expenditure on detoxification and it might be reflected in an alteration of some life history traits, such as decreased body mass (Maryanski et al., 2002). Morphometry has proved to be an appropriate tool in studies of heavy metal effects in animal. Maryanski et al. (2002) showed negative effects of both Cd and Zn on sizes of a number of body parts of carabid beetles, *Poecillus cupreus* L. In contrast, Boyd and Martens (1999) demonstrated that pea aphids are unaffected by the accumulation of the nickel in their host plant, *Streptanthus polygaloides* G r a y. Ernst et al. (1990) reported the aphid *Brachycaudus lychnidis* L. feeding on Zn-accumulating *Silene vulgaris* (M o e n c h). These examples show that aphid can tolerate elevated heavy metal levels in their bodies. Effects of heavy metal accumulation in host plants to aphids morphology have not been searched. It has been considered that heavy metal contamination in host plant is going to affect aphid morphology.

In this context, the goal of this study was to find out the relative importance of different heavy metal accumulation in host plants on morphological traits of the cabbage aphid, *Brevicoryne brassicae*.

Material and methods

Experimental design

Cabbage aphid, *Brevicoryne brassicae,* individuals were reared on heavy metal contaminated host plants (cabbage, *Brassica oleracea* L. and radish, *Raphanus sativus* L.) and on non-contaminated hosts as a control under laboratory conditions. Aphid individuals on both host plants were exposed to 3.14 mg/l copper as $CuS0_4 + 5H_20$ and 1.28mg/l lead as $Pb(NO_3)_2$, separately beginning from planting and 50 ml heavy metal solution was given to each pot daily and 50 ml water given to control plant daily. Host plants have been maintained in the separate transparent acrylic boxes (40x40x55 cm). Ten adult aphids maintained on non-contaminated host plants were released on both heavy metal contaminated and non-contaminated host plants for the initial establishment. Initial adult individuals followed and when they gave a birth, they were removed from acrylic boxes and discharged. All work was carried out in a controlled environment at an average 20 °C, RH 75% and 16 h day light. Individuals were monitored daily on each pot and adult individuals were removed for a morphological measurement. About 150 individuals were measured for each treatment.

Assessments

Six of the most important morphological characters were measured from fresh slide-mounted individuals, i.e. ultimate rostral segment (URS), second hind tarsal segment (HT), siphunculi (S), hind tibia segment (TS), total antennal segment (ANT) and also body length (BL). The statistical program SPSS 9-05 was used for statistical analysis.

Results

Heavy metal effects on cabbage reared population

Overall data analysis showed that heavy metal contamination has a significant effect on morphological expression of cabbage aphid population. There is a consistent pattern indicated that all of the six measured characters become smaller on heavy metal contaminated cabbage. There were also differences between effects of two different heavy metal accumulations and almost all measured morphological characters become smaller on Cu contaminated host plant (Fig. 1).

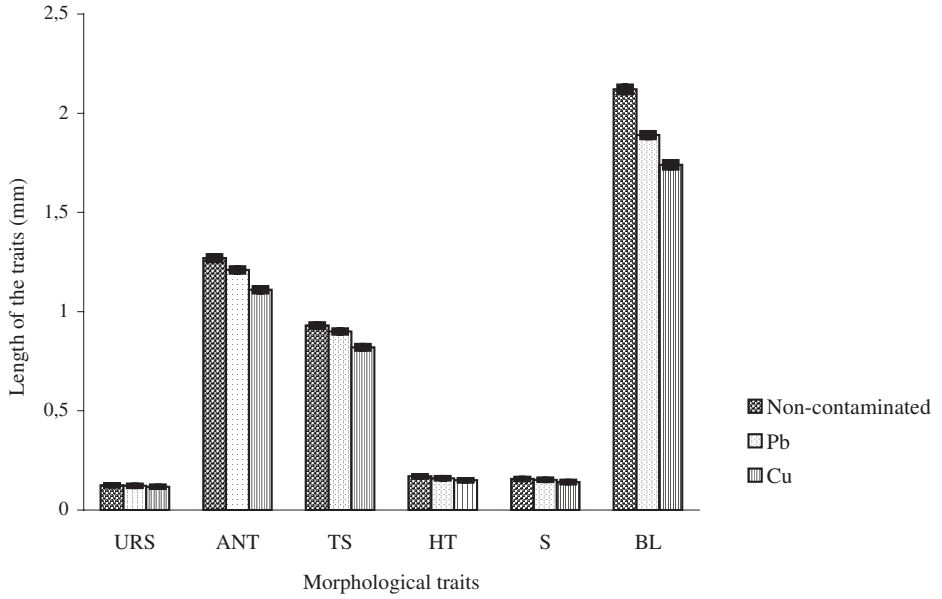

Fig. 1. Length of morphological traits of cabbage aphid population on non-contaminated and both Cu and Pb contaminated cabbage plant (Mean ± SE). (URS – ultimate rostral segment, HT – second hind tarsal segment, S – siphunculi, hind tibia segment TS, ANT – total antennal segment, BL – body length).

T a b l e 1. Comparisons of the morphological characters of *Brevicoryne brassicae* populations reared on non-contaminated and heavy metal contaminated cabbage plants (URS – ultimate rostral segment, HT – second hind tarsal segment, S – siphunculi, hind tibia segment TS, ANT – total antennal segment, BL – body length).

	Between non-contaminated and Pb contaminated host			Between non-contaminated and Cu contaminated host			Between Pb contaminated and Cu contaminated host		
Characters	**df**	**F**	**P**	**df**	**F**	**P**	**df**	**F**	**P**
URS	376	26.3	< 0.000001	404	205	< 0.000001	353	86.2	< 0.000001
ANT	376	25.8	= 0.000197	404	163	< 0.000001	353	69.8	< 0.000001
TS	375	14.2	< 0.000001	400	160	< 0.000001	348	97.8	< 0.000001
HT	375	45.4	< 0.000001	400	267	< 0.000001	348	104	< 0.000001
SIP	376	33.8	< 0.000001	404	215	< 0.000001	353	92.2	< 0.000001
BL	376	166	< 0.000001	404	412	< 0.000001	353	82.1	< 0.000001

All measured morphological characters were significantly shorter on heavy metal contaminated cabbage (Table 1).

Instead of presenting all measured characters results, ultimate rostral segment, second hind tarsal segment and body length statistical results were explained as they are much more important characters for aphids feeding on host plant. In the case of ultimate rostral segment length (URS), as can be seen clearly from Fig. 1 and Table 1, there was a significant difference between population on non-contaminated cabbage and population on Pb contaminated cabbage and also significant differences between population on non-contaminated cabbage and population on Cu contaminated cabbage. The length of rostral segment was also significantly different between population reared on Cu contaminated population and population reared on Pb contaminated cabbage host (Table 1). There were significant differences in second hind tarsal segment length of population reared on non-contaminated cabbage between both population reared on Cu contaminated cabbage and population reared on Pb contaminated host (Table 1). There was also difference in second hind tarsal segment length between population reared on Pb contaminated cabbage and population reared on Cu contaminated cabbage. Body length is the good indicator of host plant quality and directly affected from host plant physiological and morphological features, therefore its length was also considered as an important measurement. As it was similar with the above mentioned characters, there was a different expression of population exposed to heavy metal contaminated host and non-contaminated host plant. Population reared on non-contaminated cabbage expressed significantly longer body length than both population reared on Cu contaminated cabbage and population reared on Pb contaminated cabbage. Different heavy metals exposure of cabbage plant has also significantly different effects on body length of populations (Table 1).

Heavy metal effects on radish reared population

As it was shown on cabbage, overall analysis indicated significantly important effect of heavy metal contamination on cabbage aphid population reared on radish. All of the six

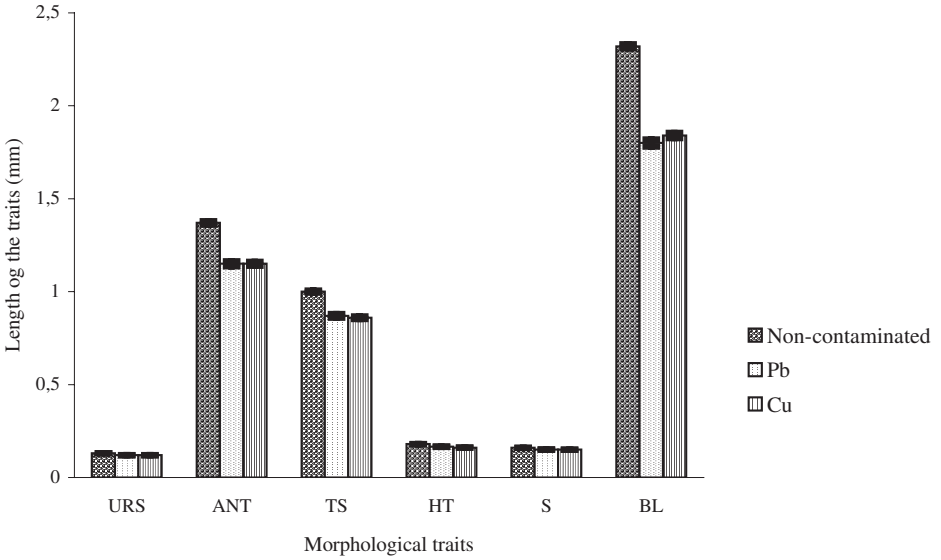

Fig. 2. Length of morphological traits of cabbage aphid population on non-contaminated and both Cu and Pb contaminated radish plant (Mean ± SE). (URS – ultimate rostral segment, HT – second hind tarsal segment, S – siphunculi, hind tibia segment TS, ANT – total antennal segment, BL – body length).

measured morphological characters of population reared on non-contamined radish were longer than both population reared on Cu contaminated and population reared on Pb contaminated radish (Fig. 2).

There was a clear pattern that all individual character become significantly smaller on heavy metal contaminated radish plant (Table 2).

T a b l e 2. Comparisons of the morphological characters of *Brevicoryne brassicae* populations reared on non-contaminated and heavy metal contaminated radish plants (URS – ultimate rostral segment, HT– second hind tarsal segment, S – siphunculi, hind tibia segment TS, ANT – total antennal segment, BL – body length).

	Between non contaminated and Pb contaminated host			Between non contaminated and Cu contaminated host			Between Pb contaminated and Cu contaminated host		
Characters	df	F	P	df	F	P	df	F	P
URS	284	287	< 0.000001	312	445	< 0.000001	173	0.061	= 0.805
ANT	284	142	< 0.000001	311	196	< 0.000001	172	0.289	= 0.591
TS	284	145	< 0.000001	311	235	< 0.000001	172	0.518	= 0.472
HT	283	236	< 0.000001	310	357	< 0.000001	172	0.283	= 0.595
SIP	284	129	< 0.000001	312	225	< 0.000001	173	0.699	= 0.404
BL	284	562	< 0.000001	312	654	< 0.000001	173	3.200	= 0.075

As it can be seen easily from both Fig. 2 and Table 2, ultimate rostral segment length of population reared on non-contaminated radish was longer than both population reared on Pb contaminated radish and population reared on Cu contaminated radish. As it was mentioned above, body length is one of the important indicator of the aphid host plant features. In parallel to general pattern, body length of the population was not exposed to heavy metal contaminated radish was significantly longer than both Cu contaminated population and Pb contaminated population. In contrast to different effects of Cu and Pb exposure on cabbage reared population, there were no significant differences in any of the measured characters between populations reared on Pb contaminated and Cu contaminated radish (Table 2).

Discussion

The potential for the uptake of heavy metals by aphids and other herbivorous insects has been shown in a different laboratory and field studies. In most of the studies their effects to herbivorous insects morphological traits are ignored. It was shown in number studies that aphids accumulate heavy metal in their tissue more than host plant body (Crawford et al., 1995; Merrington et al., 2001) and that might be due to feeding style. It can be considered that exposure to heavy metal leads to a plant eventually becoming unsuitable for herbivores. Culliney and Pimentel (1986) showed that reproduction of the aphid *Myzus persicae* (S u l z e r) was negatively affected when feeding on chemically contaminated host plant. This study indicates strong effects of both Cu and Pb on cabbage aphid population morphology when individuals reared on both Cu and Pb contaminated host plants. Results presented in Tables 1, 2 clearly indicate that exposure of two different heavy metal contaminated host plants made individuals smaller on radish and cabbage than non-contaminated radish and cabbage. There were statistically significant effects of heavy metal uptake on aphid population morphology. Thus, it can be considered that higher amount of heavy metal uptake by aphids resulted in smaller morphological traits and that might be due to either decreased food consumption-assimilation or increased detoxification cost (Maryanski et al., 2002) and alteration in energy expenditure.

This study also indicated that although heavy metal uptake has an important effect on aphids morphological traits, both type of heavy metal and type of host plant exposed also separately had important effects. Although there were significant differences in morphological traits of population between Cu and Pb exposure on cabbage, there were no significant differences between different heavy metal effects on radish.

The experimental concentration of Cu and Pb used in this study are higher than those occurring in vegetation within normally polluted areas. They therefore provide strong effects of elevated heavy metal pollution and ability of aphids to deal with this higher concentration in terms of morphological characters.

Conclusion

This study thus clearly indicates possible adverse effects of heavy metal pollution to host plant–aphid relationships. There are inconsistent patterns indicating how aphid populations are going to be influenced by the heavy metal accumulation in their host plants, thus further works are required. Especially how morphological changes influence performance of these populations and how their parasites and predators are going to be affected from this morphological induction in nature. Therefore similar research should be organized with different herbivore insects groups.

Translated by the author

Acknowledgement

I would like to thank to A. Öztürk for encouraging me to study this subject.

References

Boyd, R.S., Martens, S.N., 1999: Aphids are unaffected by the elemental defence of the nickel hyperaccumulator *Streptanthus polygaloides* (Brassicae). Chemoecology, *9*, p. 1–7.

Crawford, L.A., Hodkinson, I.D., Lepp, N.W., 1990: The effects of feeding by the black bean aphid, *Aphis fabae* S c o p. (Homoptera: Aphididae) on copper and cadmium accumulation in broad bean (*Vicia faba* L.). Environ. Geochem. Hlth., *12*, p. 245–251.

Crawford, L.A., Hodkinson, I.D., Lepp, N.W., 1995: The effects of elevated host-plant copper and cadmium on the performance of the aphid *Aphis fabae* (Homoptera: Aphididae). J. App. Ecol., *32*, p. 528–535.

Crawford, L.A., Lepp, N.W., Hodkinson, I D., 1996: Accumulation and egestion of dietary copper and cadmium by the grasshopper *Locusta migratoria* R & F (Orthoptera: Acrididae). Environ. Pollut., *92*, 3, p. 241–246.

Culliney, T.W., Pimentel, D., 1986: Effects of chemically contaminated sewage sludge on an aphid population. Ecology, *67*, p. 1665–1669.

Davison, G., Lambie, C.L., James, W.M., Skene, M.E., Skene, K.R., 1999: Metal content in insects associated with ultramafic and non-ultramafic sites in the Scottish Highlands. Ecol. Entomol., *24*, p. 396–401.

Ernst, W.H.O., Schat, H., Verkleij, J.A.C., 1990: Evolutionary biology of metal resistance in *Silene vulgaris*. Evol. Trends Plants, *4*, p. 45–51.

Maryanski, M., Kramarz, P., Laskowski, R., Niklinska, M., 2002: Decreased energetic reserves, Morphological changes and accumulation of metals in Carabid Beetles (*Poecilus cupreus* L .) exposed to Zinc- or Cadmium-contaminated food. Ecotoxicology, *11*, p. 127–139.

Merrington, G., Winder, L., Green, I., 1997: The uptake of cadmium and zinc by the bird-cherry oat aphid *Rhopalosiphium padi* (Homoptera: Aphididae) feeding on wheat grown on sewage sludge amended agricultural soil. Environ. Pollut., *96*, 1, p. 111–114.

Merrington, G., Miller, D., McLauglin, M.J., Keller, M.A., 2001: Trophic barriers to fertilizer Cd bioaccumulation through the food chain: A case study using a plant-insect predator pathway. Arch. Environ. Contam. Toxicol., *41*, p. 151–156.

Received 10. 3. 2005

Görür G.: **Vplyvy akumulácie ťažkých kovov v hostiteľských rastlinách na** *Brevicoryne brassicae* – **Morfológia.**

Touto štúdiou sa zisťovalo, ako začína vplývať akumulácia ťažkých kovov v hostiteľských rastlinách na morfologické znaky vošiek. Akumulácia medi (Cu) a olova (Pb) mala značný vplyv na morfologické znaky populácie vošky kapustovej *Brevicoryne brassicae* L. v hostiteľských rastlinách (reďkovka a kapusta). Všetky merané morfologické znaky vošky kapustovej na hostiteľskej rastline vystavenej Cu a Pb boli významne menšie. Výsledky štúdie jasne poukazujú na toxický vplyv akumulácie ťažkých kovov na vošku kapustovú a jeho následný nepriaznivý vplyv na morfológiu vošky.