Assiut Journal of Agricultural Sciences 55 (4) 2024 (115-129)
ISSN: 1110-0486 / EISSN: 2356-9840
Website: http://ajas.journals.ekb.eg/
E-mail: ajas@aun.edu.eg

(Original Article)

Assessment of the Interaction between Pesticide Applications and Heavy Metals Content in Soils and Plants

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DOI: 10.21608/AJAS.2024.301037.1376

Abstract

Soil and plant contamination with pesticides and heavy metals have significant effects on human health. There may be an interaction effect (synergistic or antagonistic) between them that can increase the risk of their presence in certain amounts. A pot experiment was conducted using four pesticides (acetamiprid, emamectin benzoate, imidacloprid, and thiamethoxam) applied on Lew mallow (*Chorcoruis olitorus*) plants grown on contaminated and uncontaminated soils. Some heavy metals and pesticide residues were determined. Treating plants with different pesticides increased the soil content of pesticide residues, and the increases were much higher in previously contaminated soils compared with the uncontaminated ones. Soil content of pesticide residues in contaminated soil can be arranged in descending order as follows: acetamiprid > thiamethoxam > imidacloprid > emamectin benzoate with increases by 707, 373, 287, and 124%, respectively, compared to the control. The highest antagonism was found between Acetamiprid and soil Zn, Emamectin benzoate and soil Pb, Imidacloprid and Mn in soil and plant, Thiamethoxam and plant Zn. The highest synergistic relationships were found between Acetamiprid with Pb and Ni in plant, emamectin benzoate with Mn and Cd, in soil and plant's Mn, imidacloprid and plant Zn, thiamethoxam and Pb in soil and Cd in plant.

Keywords: *Heavy metals, Insecticides, Pesticide residues.*

Introduction

Due to rapid industrial and agricultural growth as well as significant economic expansion, the environment is becoming more contaminated (Bhunia, 2017). Because of their longevity in the ecosystem and ability to permeate and accumulate in the food chain, toxicants are causing an increasing number of harmful health issues (Verger and Boobis, 2013). Environmental toxicants, such as heavy metals and pesticides, are ubiquitous and seriously jeopardize the structure and function of ecosystems. Natural metals that have a high atomic

Received: 2 July 2024/ Accepted: 20 October 2024/ Published online: 21 October 2024

weight and a density of more than 5 g/cm^3 are referred to as heavy metals (Zhang *et al.,* 2019). Some heavy metals are necessary for many human and plant organs, but when their concentration rises above a certain point, they become toxic. It has been shown that heavy metal pollution in agricultural soil and plants is significantly influenced by both industry and agriculture, especially in soils close to cement and electroplating facilities (Duffus, 2001; Bradl, 2005). Heavy metal buildup in human tissues can have an impact on the central nervous system and function as a pseudo-cofactor or promoter of certain health disorders, including coma, headaches, and epilepsy (Järup, 2003). Both adults and children are thought to be at risk of health problems due to heavy metal contamination (Lu *et al.,* 2014).

The ecosystem and humans have recently been exposed to several chemical toxicants, most notably pesticides (herbicides, insecticides, and fungicides), because of the rapid advancement of technology (Pastor *et al*., 2003; Özkara *et al*., 2016). Scientists define pesticides as artificial chemical substances that are applied to agricultural and other pest management situations. Consequently, in integrated pest control systems, pesticides are considered effective, economical, and efficient weapons. Uncontrolled use of pesticides is causing them to bioaccumulate in food chains, which puts mammals and other non-target animals at serious risk. Moreover, pesticides disrupt the surrounding ecosystem by their direct or indirect effects on organisms that are not their intended targets (Cooper and Dobson, 2007; Damalas and Koutroubas, 2017). In addition, pesticides can harm people and other living things when they contaminate food, drink, or the air they breathe (Kim *et al.,* 2017). Human behavior and physiology are adversely affected by pesticide exposure, regardless of the degree of exposure. Moreover, a host of illnesses, including hypersensitivity reactions, cancer, asthma, and hormone imbalances have been connected to pesticide use. They may also result in low birth weight, congenital defects, or even death (Meenakshi *et al.,* 2012; Wickerham *et al.,* 2012).

Even if a single component has the potential to be extremely hazardous, complex interactions between two or more poisonous combinations have the potential to produce unpredictable toxicity. When toxicants coexist, either as antagonism or synergism, the combined toxicity of the mixture can be effective whether in plants or soil. This combined toxicity may be more potent (synergistic), comparable (additive), or less potent (antagonistic) than the individual ones. The bioavailability and biotransformation of these toxicants are two elements that are regulating their co-occurrence (Uwizeyimana *et al.,* 2017). The combined harmful effects of heavy metals and other chemical compounds, such pesticides, on agricultural soil and plants have not been thoroughly studied up until now. Nonetheless, a small amount of research has examined the serious combination toxicity of heavy metals and some herbicides. Earthworms are among the most prevalent and accurate markers of soil toxicity (Chen *et al.,* 2015). Wang *et al.* (2015) examined the impact on earthworms of the combined toxicity of five different insecticide kinds and heavy metal (Cd). According to their findings, there were 21 ternary mixes with various interacting effects. Of them, 11 mixes showed antagonistic effects and 5 showed synergistic effects. These findings suggested that often synergistic interactions could take place.

Vegetables are susceptible to heavy metal contamination from several causes, including the usage of pesticides for vegetable treatment and the presence of heavy metals in pesticides. Therefore, the goal of this study was to determine the effect of pesticides application, which are among the most widely used pesticides in Egypt for growing vegetables, on the levels of extracted heavy metals (Zn, Ni, Pb, Mn, and Cd) in contaminated and uncontaminated soils as related the pesticide residues in both soils and Lew mallow (*Chorcoruis olitorus*) plants.

Materials and Methods

The evaluation of pesticide application effects on plant and soil contamination by heavy metals was examined. In a pot experiment conducted in the green house of soils and water department, Assiut University, Assiut, Egypt. Lew mallow (*Chorcoruis olitorus*) plants were grown on contaminated and uncontaminated soil. Contaminated soil was collected from Arab Elmadabegh area, Assiut, Egypt, where the soil was irrigated with untreated sewage water for more than 30 years. While, the uncontaminated soil was collected from the plant protection farm, Assiut University, Assiut, Egypt. Physical and chemical properties of the collected soils are summarized in Table (1).

Table 1. Some physical and chemical properties of the experimental soils

Soil properties	Contaminated Soil	Uncontaminated Soil
Particle size distribution		
Sand %	67.6	27.6
Silt %	20.0	30.0
Clay %	12.4	42.4
Texture	**Sandy Loam**	**Clay**
pH 1:2.5 (suspension)	8.21	8.09
EC 1:2.5 (m mhos/cm)	0.44	0.48
Soluble ions (meq/100 gm)		
Ca^{++}	0.75	1.25
Mg^{++}	0.50	0.38
Na^{+}	2.39	2.61
K^{+}	0.07	0.04
$CO_3^{2-} + HCO_3^{-}$	0.50	1.00
Cl^{-}	0.38	0.50
DTPA-extracted Metals (mg/kg)		
Zn	3.48	1.58
Ni	0.30	0.20
Pb	1.66	0.35
Mn	14.22	7.55
Cd	0.005	0.010
Pesticides Residue (µg/g)		
Acetamiprid	0.285	0.200
Emamectin benzoate	0.200	0.040
Imidacloprid	0.305	0.110
Thiamethoxam	0.395	0.020

Twenty Lew mallow seeds were germinated in pots filled with 1.5 kg(16 Cm diameter and 17 Cm height) of each soil type (contaminated and uncontaminated). After 2 weeks, the plants were thinned to 15 plants/ pot. Four pesticide treatments were sprayed (Distilled water as control, Acetamiprid, Emamectin benzoate, Imidacloprid and Thiamethoxam) on the plants 2 times (after 7 and 8 weeks from planting) using the hand sprayer. The pesticides ware prepared as recommended by the Egyptian Ministry of Agriculture. All agricultural practices were equally followed as recommended. At the age of 9 weeks, soil and plant samples were collected, prepared to be analyzed.

The chemical composition and structure of the pesticides used in the experiment were as follows (Fig 1):

- **Acetamiprid(C10H11ClN4)**: N-[(6-chloro-3-pyridyl) methyl]-N'-cyano-N-methyl-acetamidine
- **Imidacloprid(C9H10ClN5O2)**: 1-(6-chloro-3-pyridylmethyl)-N-nitroimidazolidin-2-ylideneamine
- **Thiamethoxam (C8H10ClN5O3S)**: 3-[(2-Chloro-1,3-thiazol-5-yl) methyl]-5-Methyl-N-nitro-1,3,5-oxadiazinan-4-imine
- **Emamectin benzoate (C49H75NO13)**: 4''-deoxy-4''-epi-methylamino-avermectin B1a/b benzoate salt; (4''R)-5-O-demethyl-4''-deoxy-4''-(methylamino)- avermectin A1a benzoate (salt) (MAB1a only)

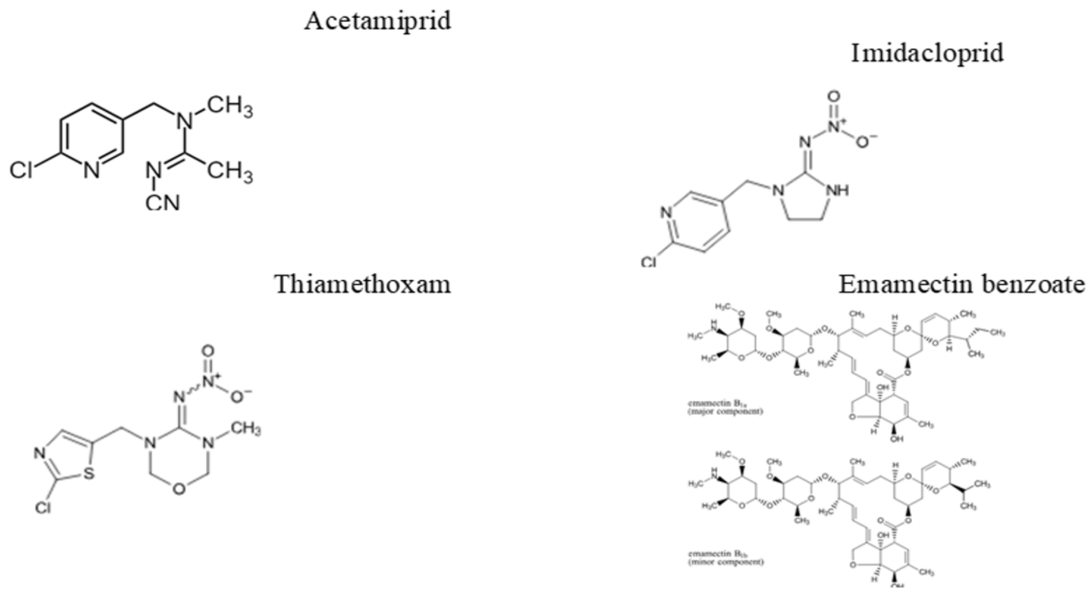


Fig.1 Structure of Acetamiprid, Imidacloprid, Thiamethoxam and Emamectin benzoate pesticides used in the investigation.

The QuEChERS method (Anastassiades *et al.* 2003) was used for pesticide residues extraction from soil samples, 3g soil samples were weighed, and 7ml of water was added to 50ml PFTE tubes and then 10ml of acetonitrile was added. The buffer-salt mixture (4g of magnesium sulfate anhydrous, 1g of sodium chloride, 1g of trisodium citrate dehydrate, and 0.5g of disodium hydrogen citrate sesquihydrate) was added and shaken immediately for one minute. The samples were centrifuged at 5000 rpm for 5min. A portion of the acetonitrile layer was filtrated using a syringe filter and directly injected into an HPLC apparatus. The HPLC system, an Agilent HPLC 1260 infinite series (Agilent Technologies), includes a quaternary pump, a variable wavelength diode array detector (DAD), and an autosampler with an electric sample valve. The HPLC system employed an ODS analytical column that measured 150 mm × 4.6 mm × 5 m.

The mobile phase

Acetamiprid: The mobile phase (acetonitrile 80% + water 20%) flow rate was 1 ml/min, the injection volume was 20 µl, and the detection wavelength was 210 nm and retention time was 4.2 min.

Imidacloprid: The mobile phase (acetonitrile 65% + water 35%) flow rate was 1 ml/min, the injection volume was 20 µl, and the detection wavelength was 210 nm. The retention time was 4.3 minutes.

Emamectin benzoate: The mobile phase (Methanol 45% + acetonitrile 40%+ water 15%) flow rate was 1 ml/min, the injection volume was 20 µl, and the detection wavelength was 205 nm. The retention time was 5.9 minutes.

Thiamethoxam: The mobile phase (acetonitrile 60% + water 40%) flow rate was 1 ml/min, the injection volume was 20 µl, and the detection wavelength was 205 nm. The retention time was 3.9 minutes.

Soil samples were collected, air-dried, crushed to pass through a 2 mm sieve, and extracted using 0.1 M diethylene triamine Penta acetic acid (DTPA) according to Lindsay and Norvell (1978). The chemical soil properties (pH, EC, OM, soluble cations and anions) were determined according to Sparks (1996) and Nelson and Sommers (1996). On the other hand, the whole plants were sampled, washed with deionized water, oven-dried at 70°C, milled and digested using the dry ash method according to Baruah and Barthakur (1997). Cadmium, Ni, Pb, Mn, and Zn were determined in both soil extracts and plant digests using a GBC 906AA Atomic Absorption Spectrophotometer.

Statistical Analysis: The treatments were set up in a RBD design with a split plot treatment arrangement. The main plots were allocated for the type of soil (contaminated or uncontaminated) and the sub-plots were allocated for pesticide treatments. Each treatment was replicated 3 times. Data were statistically analyzed according to Steel and Torrie (1980). The least significant difference at 5% probability level was used to test the significance of the means of the measured variables.

Results and Discussion

1. Effect of pesticide applications on pesticide residues in soil

The control treatments in the contaminated and uncontaminated soils contained measurable amounts of all pesticide residues under discussion (Table 2). These detected amounts may be due to the previous pesticide applications on both soils and the sewage water used for the irrigation of the contaminated soil. Mirsal (2008) concluded that the application of pesticides to plants, or harmful organisms living on soil, may move down the soil column, where they would be bound on clay minerals or absorbed on to soil organics.

Table 2. Effect of pesticides application on pesticide residues content (µg/g) in contaminated and uncontaminated soils by heavy metals

Treatments		Rt	Residues µg/g in contaminated soil	Residues µg/g in uncontaminated soil
Control	Acetamiprid	4.2	0.285	0.200
	Emamectin benzoate	5.9	0.490	0.040
	Imidacloprid	4.3	0.305	0.110
	Thiamethoxam	3.9	0.395	0.020
Acetamiprid		4.2	2.300	1.325
Emamectin benzoate		5.9	1.100	0.215
Imidacloprid		4.3	1.180	1.370
Thiamethoxam		3.9	1.870	0.420

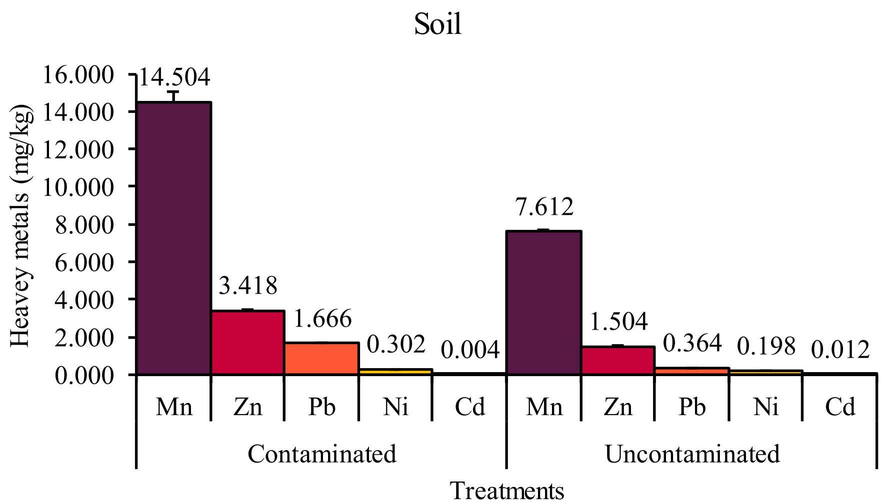
Pesticides	LOD	LOQ	Recovery %
Acetamiprid	0.01	0.05	99.02
Emamectin benzoate	0.05	0.10	92.47
Imidacloprid	0.01	0.05	98.38
Thiamethoxam	0.02	0.10	95.51

Rt: retention time, LOD: limit of detection, LOQ: limit of quantitative.

Treating the plants with different pesticides increased the soil content of pesticide residues, the increases were much higher in the contaminated soils compared to the uncontaminated ones. Soil content of pesticide residues in contaminated soil can be arranged in a descending order as follows: Acetamiprid > Thiamethoxam > Imidacloprid > Emamectin benzoate with increases by 707, 373, 287 and 124%, respectively, compared with the control. Whereas the contents in the uncontaminated soil can be arranged as follows: Imidacloprid > Acetamiprid > Thiamethoxam > Emamectin benzoate with increases from 0.110, 0.200, 0.020 and 0.040 µg/g in the control to 1.370, 1.325, 0.420 and 0.215 µg/g in the treated soils, respectively. Limits of detection (LOD) were 0.01 µg/ kg to 0.05 µg/ kg, and Limits of quantification (LOQ) were 0.1 to 0.05 µg/ for analysis insecticides. Quantifiable levels of every insecticide residue under discussion were present in control treatments in both contaminated and uncontaminated soils (Table 2). There are a variety of reasons that contribute to the existence of insecticide residues in the control, including insecticide persistence, availability in use, indiscriminate use, and lack of awareness and may occur from the use of insecticides more often or in larger amounts in areas where water flows to manage insects that could harm people's health. Wiles and Frampton (1996) revealed that compared to sandy clay loam, certain insecticide levels were found to be greater in sandy soil. Our results are consistent with these conclusions. These quantities may have been discovered because of formal insecticide applications on both soils as well as sewage water used to irrigate the contaminated soil. According to Mirsal's findings (2008), insecticides sprayed on plants or dangerous soil-dwelling organisms may migrate down the soil column and get absorbed on soil organics or bonded on clay minerals.

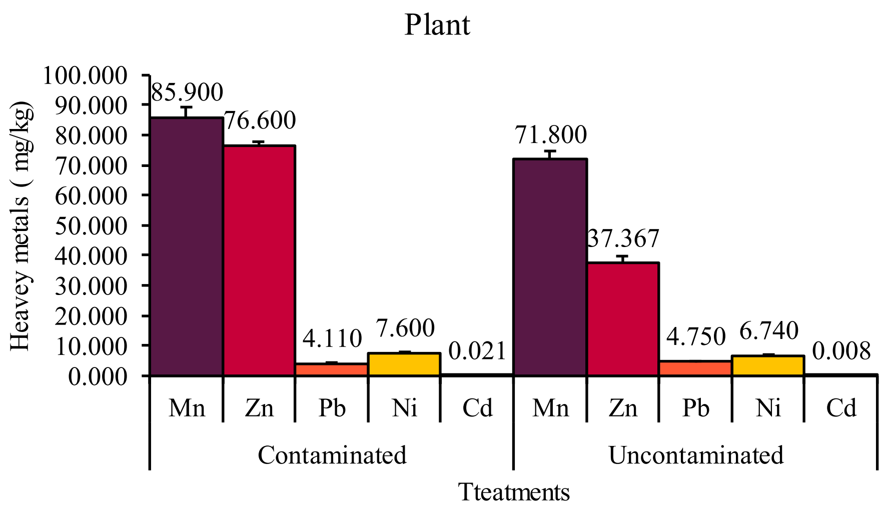
2. Main effect of soil contamination on heavy metal content in soils and Lew mallow plants

The content of all discussed heavy metals, except Cd, were significantly higher in the contaminated soil compared with the uncontaminated one (Fig 2). The higher content of Cd in the uncontaminated soil may be due to an earlier application of some pesticides and/or contaminated chemicals including fertilizers, especially phosphate fertilizers, on the soil before collecting the soil samples from the experimental farm of plant protection department, faculty of agriculture, Assiut University. Yargholi and Azarneshan (2014) reported that the long-term usage of pesticides and chemical fertilizers are the main cause of high concentrations of cadmium, selenium, arsenic and mercury in cultivated soils. Huang *et al*., (2003) found a significant increase in Cd accumulation in lettuce from the application of phosphate rock and a granulated zinc fertilizer. The content of DTPA extractable heavy metals in both contaminated and uncontaminated soils can be arranged as follow: Mn> Zn > Pb > Ni > Cd. The increase in heavy metals content in contaminated soil was by 91, 358, 53 and 127% for Mn, Pb, Ni and Zn, respectively, compared with the uncontaminated soil. In vegetables, the tolerable concentration set by WHO is 0.3, 40, 2.3, 60 and 0.003 mg/L for Pb, Cu, Cr, Zn and Ni, respectively (IARC, 2012).



	F test soil		F test
Mn	**	Ni	**
Zn	**	Cd	**
Pb	**		

Fig 2. Main effect of soil contamination on heavy metal content in soils



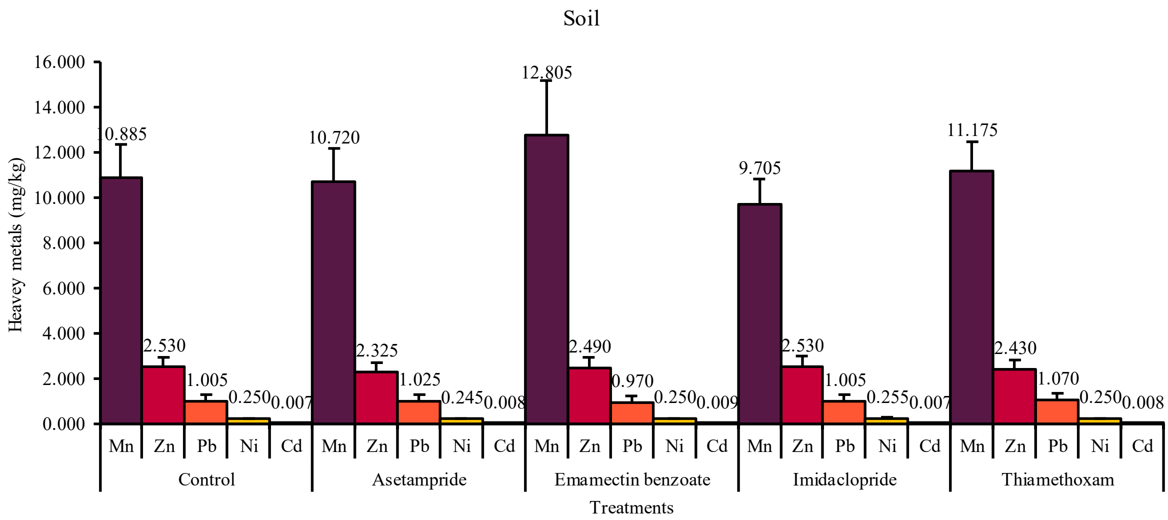
	F test plant		F test
Mn	**	Ni	*
Zn	**	Cd	**
Pb	**		

Fig 3. Main effect of soil contamination on heavy metal content in Lew mallow plants

Lew mallow plants grown on contaminated soil always contained significantly higher amounts of heavy metals than those grown on the uncontaminated soil except for Pb (Fig 3). The significant increase in Pb concentration that occurred in the uncontaminated soil may be due to the antagonistic effect of some applied pesticides on the availability of Pb which may interact with some precipitated Pb compounds to produce soluble Pb compounds. This assumption explains the higher content of Pb in plants of uncontaminated soil although the soil contains 53% Pb less than the contaminated one. Baker and Brooks (1989) and Baker and Walker (1990) reported that, irrespective of the metal concentration in the soil, hyperaccumulator plants contain more than 0.1% of Ni, Cr, Cu, Co and Pb or 1% of Zn in its leaves. The content of heavy metals in plant tissues were as follows: Mn> Zn> Ni> Pb> Cd in both contaminated and uncontaminated soils. Plants grown on contaminated soil contained amounts of discussed elements higher by 20, 163, 13 and 105% for Mn, Cd, Ni and Zn, respectively, compared with the uncontaminated soil.

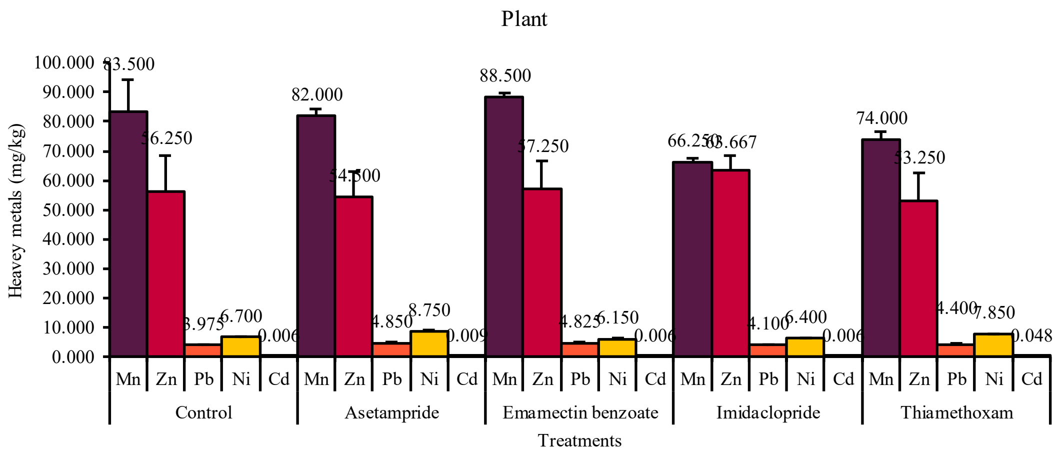
3. Main effect of pesticide applications on heavy metals content in soils and plants

Figures (4 and 5) show that there was a significant synergistic or antagonistic effect of pesticide application on heavy metal availability in soil and their content in Lew mallow plants. The highest antagonisms were found between acetamiprid and Zn in soil, emamectin benzoate and Pb in soil, imidacloprid and Mn in soil and plant, thiamethoxam and Zn in plant. Compared with the control of each element, the respective decrease in each element content due to the application of the pesticide were 8, 3, 11, 21, and 5%. Wang *et al.,* (2015) found that there was both antagonism and synergism relationship between Cd and Chlorpyrifos and Atrazine. On the other hand, the highest synergistic relationships were found between Acetamiprid and Pb and Ni in plant (22 and 31%, respectively), Emamectin benzoate and soil Mn (18%) and Cd and Mn in plant (29 and 6%, respectively), Imidacloprid and Zn in plant (13%), Thiamethoxam and Pb in soil (6%) and Cd in plant (700%), compared with their respective control.



	F test	L.S.D.$_{0.05}$		F test	L.S.D.$_{0.05}$
Mn	**	0.614	Ni	N.S.	-
Zn	*	0.129	Cd	*	0.0014
Pb	**	0.030			

Fig 4. Main effect of pesticide applications on heavy metals content in soils



	F test	L.S.D.$_{0.05}$		F test	L.S.D.$_{0.05}$
Mn	**	1.185	Ni	**	0.449
Zn	**	2.074	Cd	**	0.002
Pb	**	0.267			

Fig 5. Main effect of pesticide applications on heavy metals content in Lew mallow plants

The antagonistic effect may occur due to the interaction between pesticide residues and/ or their degrades and the element and producing precipitated compounds and/ or unbroken complexes. Whereas the synergistic effect may be due to the formation of soluble compound with the element. Chen *et al*., (2004) reported an increase in the solubility and toxic activity of Zn and Cu to ryegrass plant that produced a synergistic effect between them and 2,4-dichlorophenol (2,4-DCP) compared with 2,4-DCP free samples. Wang *et al.,* (2015) found that 11 ternary mixtures of heavy metal (Cd) with insecticides exhibited synergistic effects on earthworms, while 5 recorded antagonistic effects.

4. Interaction effect of pesticide applications and soil contamination on heavy metals content in soils and plants

Treating Lew mallow plants with pesticides had no significant effect on either DTPA- extractable Zn or Ni content in both contaminated and uncontaminated soil (Table 3). The content of respective elements ranged from 3.18 to 3.58 mg/kg and 0.30 to 0.31 mg/kg in contaminated soil and from 1.47 to 1.58 mg/kg and 0.19 to 0.20 mg/kg in uncontaminated soil. All studied pesticides had significant antagonistic effect on Mn and Zn extracted from contaminated soil. The highest antagonistic effects in the contaminated soil were found between Acetamiprid and Zn in soil and plant, Emamectin benzoate and Pb in soil and Ni in plant, imidacloprid and Mn in soil and plant, and Ni in plant, Thiamethoxam and Cd in soil. Whereas the highest synergistic effects in the contaminated soil were found between Acetamiprid and Ni in plant, Emamectin benzoate and Mn in soil and Pb in plant, Thiamethoxam and Pb in soil and Cd in plant.

On the other hand, almost all significant effects of the studied treatments in the uncontaminated soil were synergistic. This result may be due to the less contamination sources in such soils that leads to less amounts of heavy metals, except Cd, resulting in generally less interaction effects between pesticides and heavy metals. The only significant antagonistic effect in the uncontaminated soil was found between Emamectin benzoate and Cd in plants with a decrease from 0.11 mg/kg in the control to 0.001 mg/kg in the treated plant. Whereas the highest synergistic effects in the uncontaminated soil were found between Acetamiprid and Pb and Ni in plant, Emamectin benzoate and Mn in plant and Cd in soil, Imidacloprid and Zn in plant, Thiamethoxam and Cd in soil. Both synergism and antagonism relationships were reported between Pb and Acetochlor Glyphosate (Chao *et al*., 2007; Divisekara *et al*., 2018).

Table 3. Interaction effect of pesticide applications and soil contamination on heavy metals content (mg/kg) in soils

Heavy metals	Mn		Zn		Pb		Ni		Cd	
Soil Type / Insecticides	Contaminated	Uncontaminated	Contaminated	Uncontaminated	Contaminated	Uncontaminated	Contaminated	Uncontaminated	Contaminated	Uncontaminated
Control	**14.22** ± 0.22	**7.55** ± 0.10	**3.48** ± 0.05	**1.58** ± 0.06	**1.66** ± 0.01	**0.35** ± 0.01	**0.30** ± 0.00	**0.20** ± 0.00	**0.005** ± 0.00	**0.010** ± 0.000
Acetamiprid	13.91 ± 0.55	7.53 ± 0.12	**3.18** ± 0.14	1.47 ± 0.03	1.70 ± 0.01	**0.35** ± 0.01	**0.30** ± 0.00	**0.19** ± 0.01	0.003 ± 0.00	0.012 ± 0.001
Emamectin benzoate	18.10 ± 0.29	**7.51** ± 0.05	3.47 ± 0.03	1.51 ± 0.12	**1.58** ± 0.00	0.36 ± 0.00	**0.30** ± 0.01	0.20 ± 0.00	0.004 ± 0.00	**0.014** ± 0.000
Imidacloprid	**12.19** ± 0.06	7.22 ± 0.12	3.58 ± 0.07	**1.48** ± 0.02	1.63 ± 0.04	0.38 ± 0.00	**0.31** ± 0.02	0.20 ± 0.00	0.004 ± 0.00	0.010 ± 0.000
Thiamethoxam	14.10 ± 0.47	8.25 ± 0.31	3.38 ± 0.09	1.48 ± 0.02	1.76 ± 0.00	0.38 ± 0.00	0.30 ± 0.01	0.20 ± 0.00	**0.002** ± 0.00	0.014 ± 0.001
F test	**		N.S.		**		N.S.		**	
L.S.D.0.05	0.868		-		0.042		-		0.002	

Table 4. Interaction effect of pesticides application and soil contamination on heavy metals content (mg/kg) in plant

Heavy metal	Mn		Zn		Pb		Ni		Cd	
Soil type / Insecticides	Contaminated	Uncontaminated	Contaminated	Uncontaminated	Contaminated	Uncontaminated	Contaminated	Uncontaminated	Contaminated	Uncontaminated
Control	107.50 ± 0.29	59.50 ± 0.87	83.50 ± 0.29	29.00 ± 1.16	**3.90** ± 0.06	**4.05** ± 0.09	7.50 ± 0.29	5.90 ± 0.06	0.000 ± 0.00	0.011 ± 0.000
Acetamiprid	87.50 ± 0.87	76.50 ± 0.87	73.50 ± 1.44	35.50 ± 0.29	4.30 ± 0.06	**5.40** ± 0.06	9.50 ± 0.29	8.00 ± 0.23	0.010 ± 0.00	0.009 ± 0.000
Emamectin benzoate	85.50 ± 0.29	91.50 ± 0.87	78.00 ± 0.58	36.50 ± 0.87	**4.60** ± 0.23	5.05 ± 0.26	6.50 ± 0.29	5.80 ± 0.12	0.010 ± 0.00	0.001 ± 0.000
Imidacloprid	69.00 ± 0.00	63.50 ± 0.87	74.00 ± 1.16	53.33 ± 0.88	3.65 ± 0.03	4.55 ± 0.03	6.50 ± 0.29	6.30 ± 0.23	0.000 ± 0.00	0.012 ± 0.000
Thiamethoxam	80.00 ± 0.58	68.00 ± 0.58	74.00 ± 1.16	32.50 ± 0.29	4.10 ± 0.12	4.70 ± 0.17	8.00 ± 0.00	7.70 ± 0.23	**0.085** ± 0.00	0.010 ± 0.001
F test	**		**		*		**		**	
L.S.D.0.05	1.334		2.933		0.378		0.636		0.002	

5. Correlation between pesticide residues and heavy metals content

The correlation between pesticide residues and heavy metals in contaminated soil was discussed in Table (4). The generally most correlations were highly synergistic except for Zn with Imidacloprid (-0.541) and Cd with both Acetamiprid (-0.731) and Thiamethoxam (-0.663) which were highly antagonistic. Acetamiprid had a highly synergistic correlation with Zn (0.632), Ni (0.750) and Pb (0.633). Whereas, Imidacloprid had a highly synergistic correlation with Cd (0.890). On the other hand, Emamectin benzoate was highly and positively correlated with Zn (0.812), Ni (0.917), Pb (0.858) and Mn (0.788). While, Thiamethoxam was positively correlated with Zn (0.574), Ni (0.712) and Pb (0.583).

Table 4. Correlation between pesticide residues and heavy metals content in contaminated soil

Pesticide residue	Zn	Ni	Pb	Mn	Cd
Acetamiprid	0.632	0.750	0.633	0.340	-0.731
Imidacloprid	-0.541	-0.400	-0.459	-0.270	0.890
Emamectin benzoate	0.812	0.917	0.858	0.788	-0.317
Thiamethoxam	0.574	0.712	0.583	0.294	-0.663

Conclusion

The strongest antagonistic interactions seen in soil were between acetamiprid and zinc, thiamethoxam and manganese, and imidacloprid and manganese. It was found that the strongest synergistic relationships were between acetamiprid and Pb and Ni, emamectin benzoate and Mn, imidacloprid and Zn, and thiamethoxam Cd in plants. There should be more studies on the interactions between pesticides and heavy metals. The synergistic interaction between pesticide residues and heavy metals content in soil and plants means that we must prevent the application of certain pesticides on contaminated soils. Whereas the application of certain pesticides that have an antagonistic relationship with heavy metals must encouraged.

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تقييم التداخل بين اضافة المبيدات ومحتوى المعادن الثقيلة في التربة والنباتات

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الملخص

ان تلوث التربة والنباتات بالمبيدات العناصر الثقيلة له آثار كبيرة على صحة الإنسان. وقد يكون هناك تأثير تداخلى (تنشيطي او تضادي) بينهما قد يزيد من خطورة وجودهما بكميات معينة. أجريت تجربة أصص باستخدام 4 مبيدات (استامبريد، ايمامكتين بنزوات، إيميداكلوبريد وثيامثوكسام) على نباتات الملوخية (*Chorcoruis olitorus*) المزروعة في تربة ملوثة وغير ملوثة وتم تقدير بعض المعادن الثقيلة وبقايا المبيدات. أدت معامله النباتات بالمبيدات المختلفة إلى زيادة محتوى التربة من بقايا المبيدات، وكانت الزيادات أعلى بكثير في التربة الملوثة مقارنة بالتربة غير الملوثة. يمكن ترتيب محتوى التربة من بقايا المبيدات في التربة الملوثة ترتيباً تنازلياً كما يلي: أسيتاميبريد > ثياميثوكسام > إيميداكلوبريد > إيمامكتين بنزوات بزيادة قدرها 707، 373، 287 و124%، على التوالي، مقارنة مع الكنترول. أعلى تضاد وجد بين الأسيتامبريد والزنك في التربة، والإيمامكتين بنزوات والرصاص في التربة، والإيميداكلوبريد والمنجنيز في التربة والنبات، والثيامثوكسام والزنك في النبات. في حين تم العثور على أعلى العلاقات التنشيطيه بين الأسيتامبريد والرصاص والنيكل في النبات، والإيمامكتين بنزوات والمنجنيز والكادميوم في التربة والمنجنيز في النبات، والإيميداكلوبريد والزنك في النبات، والثيامثوكسام والرصاص في التربة والكادميوم في النبات.

الكلمات المفتاحية: *المبيدات الحشرية، متبقيات المبيدات، المعادن الثقيلة*