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Analysis of the impact of soil contamination by deltamethrin and heavy metals on wheat quality and yield

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ABSTRACT

The presence of pesticides in wheat is a problem closely related to the use of these substances to control pests (insects, diseases and weeds) during wheat production. The aim of the study is the presence (concentration) of pesticides including Deltamethrin which are used to ensure high yield and to protect crops from pests, can reduce the quality and quantity of wheat. Heavy metals often reach agricultural lands through the use of pesticides and chemical fertilizers, while dust generated by vehicles and other activities can contribute to the deposition of these elements in the soil. Heavy metals are chemical elements with high density and are solid, including substances such as: lead (Pb), cadmium (Cd), mercury (Hg), chromium (Cr), nickel (Ni) and copper (Cu). The study was conducted in the Dukugjin area, which has an area of 1562 km² and aims to assess the concentrations of heavy metals and pesticides in agricultural soils. The results of the study for wheat show that in some cases, the concentration values exceed the norm parameters. For example, the samples for the cadmium position (X1) have an average value of 0.061 $mg \cdot kg^{-1}$, while for nickel the average value is 0.119 $mg \cdot kg^{-1}$. For the samples for the position (X2), cadmium has an average value of 0.231 $mg \cdot kg^{-1}$, while copper reaches an average value of 0.341 $mg \cdot kg^{-1}$. In the analysis of agricultural soil, the concentration of nickel is relatively high, with an average value of 4.966 $mg \cdot kg^{-1}$, while for samples (X2), the value reaches a much higher level of 8.553 $mg \cdot kg^{-1}$. Regarding deltamethrin, in samples from position (X2).

Keywords: heavy metals, pesticides, wheat, food safety, concentrations, soil.

INTRODUCTION

Pesticides are often applied directly to agricultural land by aerial spraying or by agricultural machinery, with Deltamethrin being the most widely used pesticide due to its economic cost (Hoxha et al., 2023; Talha et al., 2025). When large amounts are used or applied very close to harvest, pesticides are deposited in the grain. Pesticides are used to control pests and diseases during the grain growth period (Gashi et al., 2023; Hoxha et al., 2023). These chemicals accumulate in the leaves, seeds, and soil (Shala et al., 2023; Gashi et al., 2023). After harvest, pesticides accumulate in the grain, especially if the grains are not properly handled after harvest, such as cleaning or storage in unsafe conditions that allow chemical residues to remain in the product (grain). Consumption of grains or other agricultural products containing pesticides risks human health (Harian et al., 2025; Hoxha et al., 2023). Pesticides cause immediate poisoning (symptoms such as headaches, vomiting, etc.), or long-term effects such as nervous system damage, cancer, and hormonal disorders (Shala et al., 2023; Nanlohy et al., 2024). Some pesticides negatively affect immune system function and cause hormonal dysfunction.

Deltamethrin – it is a pyrethroid pesticide, which is highly toxic to non-cellular soil organisms, including microorganisms and insects. It interferes with soil microbial activity, reducing the soil's ability to maintain a healthy and balanced ecosystem (Shala et al., 2023; Gashi et al., 2023). The presence of deltamethrin in soil causes a reduction in the biodiversity of organisms that contribute to soil health. Including various types of insects and microorganisms that are important for nutrient cycling and ecological processes. A pyrethroid insecticide is used to control insects such as snails, various types of bees, and other insects that attack wheat seeds and leaves (El Amarty et al., 2024; Dreshaj et al., 2022). The maximum residue limit (MRL) for deltamethrin in wheat is in the range of 0.05–0.2 $mg \cdot kg^{-1}$, depending on national legislation.

Lead-deltamethrin

Lead, on the other hand, is a heavy metal found in soil due to industrial pollution and the use of expired pesticides, its concentration increases (Dreshaj et al., 2022; Zbykovskyy et al., 2024). When Lead is in the soil, it binds to other parts of the soil and is deposited in plants, increasing the risk of food contamination (Shala et al., 2023; Purwono et al., 2024). If lead and deltamethrin are present at the same time in agricultural soil, several interactions occur. Lead affects the activity of microorganisms, which then affects the degradation of pesticides, then the risk for normal plant development increases.

Deltamethrin

This pesticide damages soil microorganisms and can change the structure of the soil ecosystem. deltamethrin causes accumulation in plants, which can increase the risk of food contamination and consequences for human health (Hardyanti et al., 2024; Dreshaj et al., 2022).

Cadmium-deltamethrin

The heavy metal cadmium and the pesticide deltamethrin, if present together, lead to an accumulation of toxins in plants. Deltamethrin penetrates the plants, while cadmium affects the absorption and stimulates other toxic substances in chemical reactions in the soil (Agustina et al., 2024; Kovaçi et al., 2023). The presence of cadmium and deltamethrin in agricultural soils poses additional risks to human health through food contamination. Deltamethrin is a pesticide toxic to humans and causes harm if consumed at high levels through contaminated food (Rahoui et al., 2024; Dreshaj et al., 2023).

Mercury-deltamethrin

Together in agricultural soils, these two substances occur in several possible chemical interaction reactions and several biological effects (Dreshaj et al., 2022; Dreshaj et al., 2023). Both substances have harmful effects on soil microorganisms and their biodiversity. These chemical substances cause increased toxicity to soil organisms, leading to a deterioration of the biological structure of the soil and a decrease in its fertility (Ghaib et al., 2024; Dreshaj et al., 2023). Deltamethrin affects the activity of beneficial microorganisms in the soil, if mercury is present, it causes a worsening effect on these organisms in agricultural soils (Dreshaj et al.2022; Dreshaj et al., 2023).

Chromium-deltamethrin

Both substances have specific and general toxic effects on microorganisms and plants. They have harmful effects on the soil ecosystem, including a decrease in microbiological activity. Deltamethrin interferes with chromium, affecting the development of plants and microorganisms. This occurs because the pesticide affects the chemical structure of the soil, creates the ability to modify plants, or worsens its toxicity (Dreshaj et al., 2022).

Nickel-deltamethrin

The interaction of these two substances causes several different effects on the health of the soil, plants, and other organisms. Both substances are toxic to various organisms in the environment and affect the soil ecosystem. It creates the ability to affect plant metabolism and microbiological activities important for maintaining soil health (Boughou et al., 2024; Dreshaj et al., 2022). When present together, they exacerbate each other, causing greater damage to microbial biodiversity. This can lead to a decrease in soil microbial activity, making it less able to decompose organic matter and maintain nutrient cycles.

Copper-deltamethrin

Both substances are toxic to soil microorganisms. Their combination causes greater damage to microbiological biodiversity, leading to a decrease in the activity of beneficial microorganisms. They contribute to nutrient cycles and the decomposition of organic materials (Dreshaj et al., 2023; Rahoui et al., 202024). This process hinders the healthy development of the soil and reduces its efficiency in supporting plants.

MATERIALS AND METHODS

Soil and wheat samples were taken 5 days after treatment with deltamethrin [Month (June – July)] 2024. Soil and wheat samples were sent to the Laboratory of the Agricultural Institute in Peja. While deltamethrin samples were sent to the commercial laboratory "Ontario" Canada (Dreshaj et al., 2023). The results are the average of three samples at each location (X1 – Peja, X2 – Gjakova). Some of the most common analytical methods for the identification of deltamethrin are: liquid chromatography with mass assisted mass spectroscopy (LC-MS), gas chromatography (GC), UV-vis spectroscopy (Dreshaj et al., 2022), immunoanalytical methods (ELISA), nuclear magnetic resonance spectroscopy (NMR). Analytical methods used for the identification and measurement of heavy metals in soil and agricultural products such as wheat – Atomic Absorption Spectroscopy (AAS) (Dreshaj et al., 2023). The case study was conducted in the Dukagjini plain, a region known for wheat cultivation. The relevant samples were collected and sent to the laboratory for detailed analysis. The results obtained were compared with international standards and comparative analyses were made for their evaluation (Table 1 and Fig. 1).

RESULTS AND DISCUSSION

The levels of heavy metals in grain vary and depend on many factors, including soil type, pesticide use, industrial pollution, and environmental contamination. The specific levels of heavy metals in grain vary depending on their concentration in agricultural soil. They are usually expressed in units of milligrams per kilogram (mg·kg^{-1}) and are studied to ensure that the level of contamination is acceptable for consumer health. Here are some common levels of heavy metals in grain, based on international food safety standards such as (WHO) and the European Commission.

The excessive use of pesticides contributes to the development of resistance to some antibiotics and chemical substances. Pesticides negatively affect the environment by polluting the soil, water, and air. They cause beneficial soil organisms and negatively affect biodiversity. Furthermore, pesticides released into the air spread and pollute natural habitats, endangering local biodiversity. As a result of this study, they have also affected the pH of the soil, in some cases by reducing the pH (acidity) samples X1(c), depth 35 cm, distance

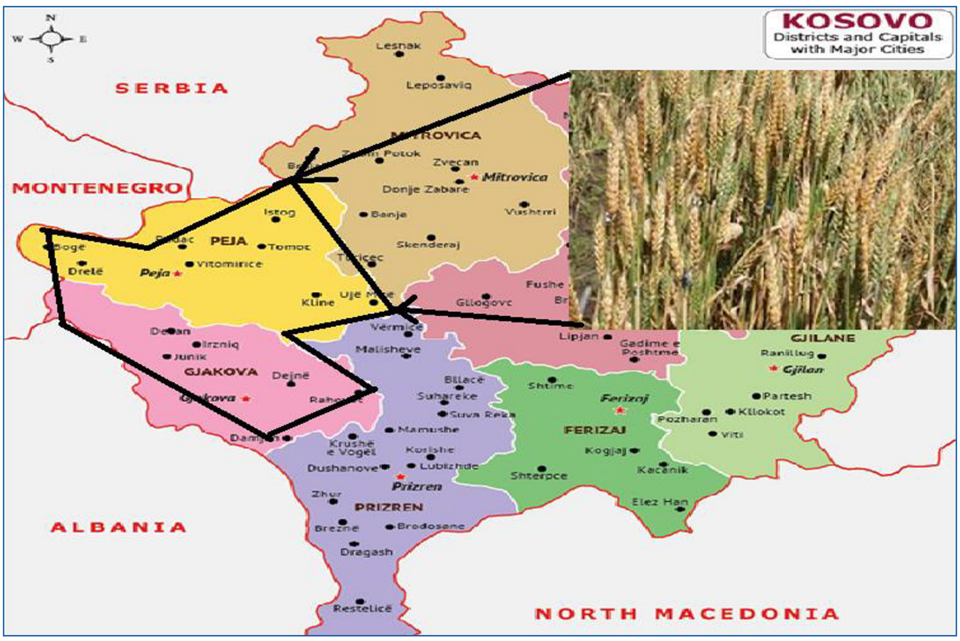


Figure 1. Geographic location of sampling stations for soil and grain samples in the Dukagjini Plain

Table 1. Heavy metal values in wheat/soil/deltametrine according to the World Health Organization (WHO) and the European Commission (mg·kg^{-1})

No	Elements	The average value of heavy metals in wheat mg·kg^{-1}	Average value of heavy metals in agricultural soil mg·kg^{-1}	Average deltamethrin value in agricultural soil mg·kg^{-1}	Average deltamethrin value in wheat mg·kg^{-1}
1	Lead (Pb)	0.05–0.3	10–300		
2	Cadmium (Cd)	0.01–0.1	0.1–5		
3	Mercury (Hg)	0.001–0.01	0.05–1	0.1–10	0.05–0.2
4	Chromium (Cr)	0.05–0.2	10–100		
5	Nickel (Ni)	0.1–1	10–100		
6	Copper (Cu)	0.2–3	10–50		

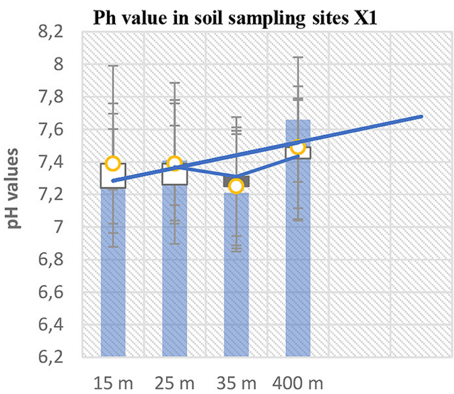
35 m, with pH 7.23, these values are presented in (Table 2). While the other samples studied have an average pH of 7.39–7.52., these values are presented in Figure 2.

The excessive use of deltamethrin in some sampling locations has changed the microbiological structure of the soil, in the cycle of nutrients such as nitrate and ammonia. Such changes can then have a change in soil pH as a result in this study in some locations we have a decrease in wheat yield. This process was observed in soils that have low pH levels or are sensitive to chemical changes, samples X1(b) pH = 7.24. Nitrification and denitrification reactions are biological processes where bacteria convert (NH_3) to nitrite (NO_2^-), and then to nitrate (NO_3^-) which are available forms of nitrogen for plants. This process affects nitrogen balance and soil fertility. Denitrification occurs under anaerobic conditions when bacteria use nitrates as electron acceptors and convert them to molecular nitrogen (N^2), thus losing nitrogen to the atmosphere. The chemical reactions of heavy metals in soil are complex and are associated with soil minerals (e.g. clays, oxides, carbonates) or as ions (Pb^{2+}, Cd^{2+}).

The results for soil pH show that in sampling sites with low pH (acid), there is decomposition of heavy metals Pb from the liquid state, passing into ionized form. Complex compounds are formed with organic matter such as (fulvic and humic acids), these acids have slowed down their movements in the studied agricultural soil. The

Table 2. pH value in soil sampling sites (Peja – Gjakovo)\

Distance	X1 (June/July, 2024 Peja)				X2 (June/July, 2024 Gjakovo)			
	X1 (a)	X1 (b)	X1 (c)	Average	X2 (a)	X2 (b)	X2 (c)	Average
	0–35 cm	0–35 cm	0–35 cm		0–35 cm	0–35 cm	0–35 cm	
15 m	7.33	7.24	7.61	7.39	7.53	7.55	7.65	7.57
25 m	7.41	7.26	7.51	7.39	7.43	7.44	7.66	7.51
35 m	7.21	7.31	7.23	7.25	7.71	7.52	7.62	7.62
400 m	7.66	7.42	7.41	7.49	7.53	7.51	7.52	7.52



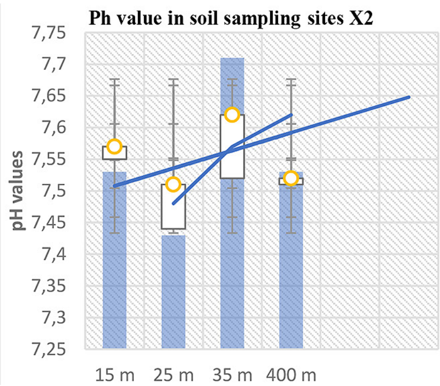


Figure 2. Soil pH value graph

presence of oxides and hydroxides in agricultural soil has interacted with heavy metals such as (lead and cadmium), they are deposited as their oxides. This complex is not absorbed by plants and other soil microorganisms. The process is slow and takes time to stabilize chemical and biological processes in agricultural soil.

The measurement of organic carbon is essential for the maintenance and health of the soil, it improves its ability to hold water and air and plays a fundamental role in the maintenance and development of plants. It is a source of many organic nutrients for plants such as (nitrogen, phosphorus, and calcium), these values are presented in (Table 3). In this study, the results for organic carbon show a reduced value for the components X1(b), with a value of 0.33 %, this process occurred as a result of the presence of deltamethrin and the presence of several heavy metals above normal parameters, the values are presented in Figure 3.

Research shows that the presence of deltamethrin in agricultural soils has negatively affected soil microorganisms (such as bacteria and fungi), which are important in decomposition processes. The reduction of organic carbon negatively affects microorganisms by causing the accumulation of organic carbon and reducing its cycle. The results of the study show the preservation of organic carbon, which are simple and easily

Table 3. Percentage of organic carbon at different soil depths (Peja – Gjakova)

Distance	X1 Peja (Percentage of organic carbon) %				X2 Gjakova (Percentage of organic carbon)%			
	X1(a)	X1(b)	X1(c)	Average	X2(a)	X2(b)	X2(c)	Average
	0–35 cm	0–35 cm	0–35 cm		0–35 cm	0–35 cm	0–35 cm	
15 m	0.59	0.39	0.49	0.49	0.59	0.59	0.43	0.53
25 m	0.56	0.33	0.42	0.43	0.51	0.45	0.59	0.51
35 m	0.66	0.59	0.44	0.56	0.53	0.67	0.51	0.57
400 m	0.44	0.49	0.47	0.46	0.47	0.69	0.50	0.55

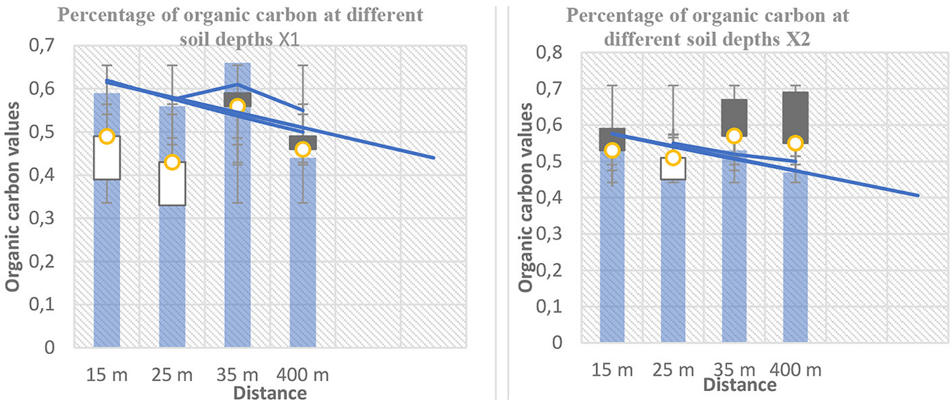


Figure 3. The value of organic carbon in soil

Table 4. Results of heavy element values and the pesticide Deltamethrin in wheat (mg·kg^{-1})

Elements	X1 Peja					X2 Gjakova				
	X1(a)	X1(b)	X1(c)	Average	%	X2 (a)	X2 (b)	X2 (c)	Average	%
Lead	0.011	0.019	0.029	0.019	6.49	0.023	0.078	0.45	0.183	16.19
Cadmium	0.034	0.089	0.058	0.061	20.80	0.467	0.156	0.067	0.231	20.43
Mercury	0.0002	0.0023	0.0019	0.0014	0.481	0.0034	0.0054	0.0078	0.0055	0.49
Chromium	0.011	0.028	0.0087	0.0159	5.42	0.023	0.034	0.056	0.037	3.27
Nickel	0.029	0.098	0.23	0.119	40.07	0.089	0.12	0.29	0.166	14.68
Copper	0.029	0.089	0.02	0.046	15.68	0.031	0.28	0.98	0.341	30.16
Deltamethrin	0.034	0.059	0.002	0.031	10.57	0.23	0.27	0.003	0.167	14.77

degradable substances such as (sugars, and alcohol), simple parts of biochemical processes that microorganisms use to create energy and accelerate decomposition processes.

Heavy metals remaining in cereals migrate to other food products (such as bread, pasta, and cereals), contributing to the presence of chemical residues in consumers' daily diets. Industrial activities such as mineral extraction plants, battery production, or metal processing release lead, cadmium, arsenic, and other elements into the air, water, and soil, their values are presented in (Table 4 and Figure 4). Some heavy metals react with acids to form hydrogen and salts. Studies have shown that iron reacts with hydrochloric acid (HCl) to form ferric chloride ($FeCl_2$) and hydrogen (H_2). Some heavy metals, especially under conditions of high pressure and temperature, form carbonates. For example, calcium reacts with CO_2 to form calcium carbonate.

The study of heavy metals in agricultural soils is a well-known environmental and agricultural problem. These substances accumulate and negatively affect soil productivity and plant health, as well as pollute food and water resources. Heavy metals affect the microbiological activity of the soil and the stability of its structure, reducing its ability to retain moisture and nutrients. They can damage plant roots and interfere with their ability to absorb nutrients, limiting plant growth and development. These metals bioaccumulate in plants, and contaminate food, making them harmful to the health of consumers.

Lead in agricultural soil has negative effects on the activity of soil microorganisms, affecting the degradation of pesticides such as Deltamethrin. The presence of Deltamethrin has damaged soil organisms, in some sampling sites it has changed the structure of the soil ecosystem, affecting the mode of action of Lead to be unavailable to plants, their values are presented in (Table 5 and Figure 5). Lead is more available to plants under conditions with low pH (acidic). When the soil pH is low, lead often exists as the Pb^{2+} ion, which is more available for plant uptake. When the pH increases (basic), lead forms immobile complexes, such as lead carbonate, which make it more difficult for plants to absorb it. For example, in soil with a low pH, complex reactions occur such as $Pb^{2+} + CO_3^{2-} \rightarrow PbCO_3$ (lead carbonate), while in soil with a higher pH $Pb(OH)_2$ is formed. The values of organic carbon in the soil in the two

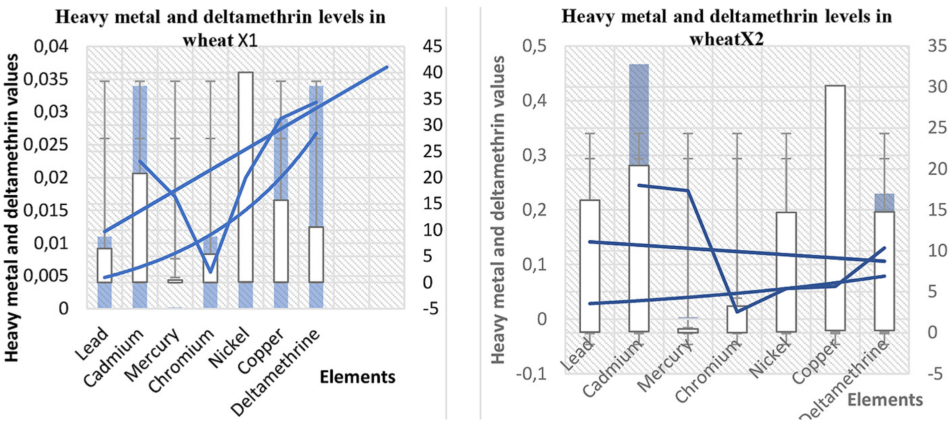


Figure 4. Graph of heavy metal and deltamethrin values in wheat

Table 5. Results of element and deltamethrin values in agricultural soil (mg·kg^{-1})

Elements	X1 Peja					X2 Gjakova				
	X1(a)	X1(b)	X1(c)	Average	%	X2 (a)	X2 (b)	X2 (c)	Average	%
Lead	1.27	0.05	0.029	0.449	4.33	2.49	0.99	2.34	1.94	10.42
Cadmium	0.02	0.251	0.034	0.101	0.97	2.41	1.39	1.23	1.676	9.01
Mercury	0.0031	0.0034	0.017	0.0078	0.08	0.002	0.002	0.001	0.0016	0.01
Chromium	1.23	0.56	0.45	0.746	7.19	0.030	0.231	0.034	0.098	0.52
Nickel	5.67	4.56	4.67	4.966	47.89	7.98	8.34	9.34	8.553	45.94
Copper	2.45	3.45	3.73	3.216	31.02	4.29	2.98	5.44	4.236	22.75
Deltamethrin	0.23	0.02	2.4	0.883	8.52	2.87	2.23	1.24	2.113	11.35

regions studied in some locations are worsened by its presence, at a distance of 25 m the X1(b) samples have a low value of 0.33%, with an average percentage of three locations, of 0.43%. The presence of Lead accumulated in wheat increases the risk of food contamination. In the studied samples (X2) a high percentage of Pb is observed, which varies with an average of 16.19%, while the value of deltamethrin with an average of 14.77%, these values are presented in Table 4 and Figure 4. The results of the study on the presence of cadmium in wheat show high levels in two samples (X1) Peja, with a value of 20.80%, and samples (X2) Gjakova, with a value of 20.45%. This value increases the toxicity of plants and soil organisms, causing severe damage to the root system of plants and microorganisms that contribute to soil health. This process has created the ability to exacerbate the toxic effects of cadmium. Since cadmium interferes with the ability of plants to utilize nutrients, the presence of Deltamethrin has impaired plant growth, causing additional stress to the plants, and resulting in reduced yield.

If both substances are present at the same time, the process of accumulation of toxins in plants and food products begins. This will have serious consequences for the health of consumers of contaminated agricultural products, including the risk of mercury poisoning and neurotoxicity from Deltamethrin. The presence of Mercury and Deltamethrin in two sampling locations (X1) varies with an average percentage value of 0.08% and the samples (X2) vary with a value of 0.01%, this concentration has severely damaged the soil fauna, including insects and other organisms, important for natural recycling processes. This chemical process has caused a rapid decline in soil biodiversity and stops the natural cycles of nutrients. The increase in the toxicity of Mercury and Deltamethrin contributes to the weakening of the structure and quality of the soil. It leads to a soil-less rich in beneficial microorganisms and a lower ability to retain nutrients and develop healthy plants. This process slows down the decomposition processes and reduces the availability of nutrients to plants. The value of Mercury in wheat varies with an average at the sampling site (X1) with an average value of 0.481%, while in samples (X2) it varies with an average value of 0.490%, Deltamethrin in the three samples X1 (a, b, c) varies with an average value of 15.77%.

The presence of chromium in agricultural soils is observed to affect the way other substances decompose and degrade in the soil. Chromium has interfered with the activities of microorganisms that are responsible for the degradation of pesticides. Deltamethrin has acted by causing a longer accumulation of the pesticide in the soil. The combined toxicity of the two soil elements has affected the accumulation of the soil and has increased the risk of environmental and food contamination. The presence of nickel in agricultural soils together with the pesticide Deltamethrin has caused multiple toxic stress to the plants in this study. The yields in these studied soils have a reduction in the planned wheat production of 5000 kg. In the sample sites X1(a) per 1 hectare, there was a yield of 3500 kg, while in the sampling sites X1(c) 3800 kg per hectare. The study notes that the nickel element in the samples of samples X1 and X2 has an added value in concentration, it is extremely high, varying with an average value in samples (X1) of 47.89%, while samples (X2) varies with an average, value of 45.94%.

In some positions, the results show that nickel has inhibited plant growth and development due

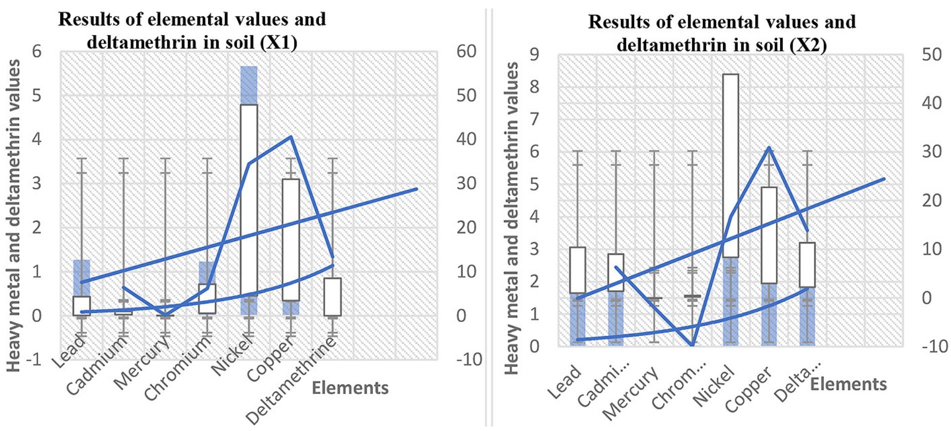


Figure 5. Graphical representation of element and deltamethrin values in soil

to its high value, while Deltamethrin has begun to damage the plant's defense systems and reduced their ability to cope with nickel toxicity. This interaction has caused damage to plant growth and reduced plant yields from the average of the samples of the studied region X2(a) 3700 kg per hectare with a reduction in yield of 1300 kg per hectare. Deltamethrin has created chemical conditions that inhibit the decomposition processes of organic materials and has negatively affected soil health. This process has reduced the availability of nutrients in the soil and has inhibited plant growth, making them more susceptible to diseases and stress. The high level of copper has caused direct damage to specific plants. While deltamethrin together with copper has caused an interference in plant defense and reduced their ability to fight stress and other diseases in plants.

CONCLUSIONS

Soil and grain contamination by heavy metals and deltamethrin is a major environmental and health problem. Heavy metals, such as lead, cadmium, and mercury, often occur as a result of industrial activities, agriculture, and inappropriate waste management. They accumulate in the soil and, through the food chain, can reach agricultural products such as cereals, causing negative consequences for human and animal health. The results of this study show that heavy metals and Deltamethrin, an insecticide used in agriculture, are toxic to many organisms and have caused soil and water contamination. Also, based on the analytical results, it is noted that it has accumulated in the soil and cereals, increasing the risk for consumers.

In conclusion, contamination by heavy metals and deltamethrin requires urgent measures to reduce the use of these substances, improve agricultural practices, and to require increase environmental monitoring. It is necessary to develop strategies for recycling materials and cleaning up the soil to protect public health and ecosystems.

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