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Toxic effect of lead and cadmium on morphological and chemical characteristics of *Trigonella foenum-graecum*

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Abstract

The present study aimed to investigate the impact of cadmium and lead on the phenotypic and physiological characteristics of *Trigonella foenum-graecum* L. in soils with varying concentrations of these two elements. Additionally, the study aimed to examine the effect of cadmium and lead on the active chemical compounds in the plant and their medicinal function. The experiment involved planting and monitoring plant seeds for a duration of seven months, from November 2020 to May 2021. Observations and results were recorded after subjecting the plants to different concentrations (10, 25, 50 ppm) of cadmium, lead, and a mixture of the two elements. The highest salinity level of 1.848 mg/L was recorded in the soil treated with 50 ppm concentration of cadmium, while the lowest salinity level of 0.884 mg/L was observed in the soil treated with a mixture at a concentration of 10 ppm. The treatment with a mixture of cadmium and lead at a concentration of 50 ppm resulted in the highest number of active chemical compounds, with 41 compounds detected, while the control treatment exhibited the lowest number of active compounds, with 21 compounds identified.

Key word: cadmium, lead, *Trigonella foenum-graecum*, pollutants

Introduction

Heavy metals are among the most important environmental pollutants (Hamaze *et al*., 2020) it is related to the processes of growth, development and reproduction in living organisms it can become toxic in high concentrations such as lead and cadmium (MDE, 2003) it has harmful effects as it is highly toxic and non-degradable it has along biological half-life in addition to its ability to bio accumulate in different parts of the body as well as the accumulation across the levels of the food chain, which is called bio magnification its ability to cause cancerous tumors as well as to combine with other elements that may form new, more toxic compounds (Younus and AL-Khafaji, 2020).

Lead is one of the most toxic heavy metals in the environment, plants respond to the toxic effects of lead in different ways (Gupta *et al*., 2009) the element interacts with cellular compounds and increases the thickness of the cell wall, plant cell wall usually contain pectin, this process is the cornerstone of plant cell resistance to lead toxicity (Eun *et al*., 2002) with increased to organ and tissue infrastructure, chloroplasts, nucleus, cell wall and cell membrane in plants, this damage can cause loss of organelle function and can effect normal physiological protein synthesis and cell division with plant species (Salazar and Pignata, 2014).

Cadmium is a highly toxic trace element even if it appears in low concentrations, it affects the opening and closing of stomata and the process of transpiration and photosynthesis in plants, plants grown in soil containing high levels of cadmium show visible symptoms of infection such as stunted growth, browning of root tips and eventually death (AL-Gizzi *et al*., 2020).

In the current study was used *T.foenum-graecum* because of its medical importance, its seeds containing many active substances in clouding alkaloids Trigonelline and choline and compounds of calcium, phosphorous and vitamin D. In addition to 25% proteins,50% carbohydrate, 6% fixed oil, 1.05% volatile oils, 28%gels and 25% alkaloids (AL-Mayah, 2013).

Materials and methods

The study was conducted in the Ecology Department of the College of Science, University of Basrah for a period of six months, from November to May for the academic year (2020-2021) for the purpose of knowing the effect of cadmium Cd and lead Pb pollution on plant Trigonella foenum-graecum.

Conduct the experiment.

After observing the growth of the plant for a period of two months and the appearance of its true leaves, at a height of 30 cm.The plants in the experiment were irrigated with the prepared concentrations of both components and the mixture, while the control plants (comparator) were irrigated with distilled water.

Soil

After completing the experiment (four months), the potting soil for each plant was taken and concentrated and dried at room temperature, then cleaned and sieved with a sieve whose holes size is 63 mm and kept in plastic containers for the purpose of making the required measurements on them.

Measuring the physical and chemical properties of the soil

1-Temperature measurement

The temperature in the laboratory was measured with a graduated mercury thermometer from 0-100 C^{o}, by placing the thermometer in the laboratory and leaving it for five minutes, then recording the reading for it.

2- pH and salinity measurement

Measure the pH and salinity according to the method described before Estefan *et al*.(2013), take a weight of 25 g of soil and put it in a glass beaker, add 75ml of distilled water to the glass beaker, shake well and then leave for 24 hours, then the solution was filter papers, then the pH of the filter was determined using a pH-meter a model HQ411d American made, salinity was estimated with a salinity meter model SD320 Con German –made and the output is expressed in mg/L.

3- Measurement of soil total organic carbon

Amount of total soil organic carbon by Weaver and Clemmets (1973) incineration method it takes 1 g of soil, then it was placed in an eyelid with a known weight and then put into the restoration furnace at a temperature 550 C^{o} for 48 hour, the sample was weighed after it was extracted from the furnace and according to the weight difference, which is the amount of total organic carbon, according to the equation

Total carbon weight= weigh the syringe with the soil before burning weight the syringe with the soil after burning*100

Observer indicators and the chemical of the plant

1-Measure the height of the plant and the length of the leaves

Both the height of the plant and the length of the leaves of the plant used in the study were measured from the surface of the soil to the top of the plant with three repetitions using a ruler, express the result in centimeter according to the source Ogbo *et al*.(2010).

2- Measurement of total chlorophyll and carotene

Estimated each of chlorophyll A, chlorophyll B and total chlorophyll by crushing with 80% acetone according to the method mentioned in Abbas (1987), take 1g of fresh leaves of the plant and add 20 ml of acetone in a concentration 80% (prepared from 80% acetone to which 20 ml distilled water has been added), the sample was left for 24 hour after which it was crushed in a ceramic mortar until green plant extract is obtained the samples were filtered by filter paper and the remnants of the ceramic mortar were washed with 5 ml of acetone to obtain all the extracts, complete the volume to 50ml then measure the total chlorophyll in the filtrate using a Spectrophotometer on both wavelengths (663 chlorophyll A, 645 chlorophyll B) nm, the readings were recorded at each wavelength, then the following equation was used to find the final value of total chlorophyll :

$$\text{Total chlorophyll}= [20.2(A645)+8.02(B663)]*V/1000*W$$

In the same way, the concentration of carotene in the plant was estimated at a wavelength 480 nm depending on the method (Kirk and Allen, 1965) according to the equation:

$$\text{Carotene}= [A\ 480+(0.114*A663)-(0.638*A645)]*V/1000*W$$

3- Measurement of the total organic carbon of plant

The amount of total organic carbon of the plant according to (Ball, 1964) incineration method, after drying the plant and grinding them with ceramic mortar, take 1g of the plant and placed in eyelid of known weight, and then the eyelid was placed in the incineration furnace at temperature of 450 C^o for 24 hour, the sample was weighed after extracting it from the furnace and according to the weight difference, which is the amount of total organic carbon of the plant according to the equation below

W.T.C=W. eyelid with the plant before burning-W. eyelid with the plant after burning*100

4- Chemical determination

Estimated chemicals in the plant according to (Haarborn, 1984) after drying and grinding the plant take 1g from dried and ground plant and placed in 100 ml glass beaker then add to it 10 ml of ethyl alcohol concentration of 70%, shake well and put the mixture on the Megnetic stirrer for three hours, the extract was left for 24 hour and then filtered through filter papers the filtrate was collected and placed in a test tube and sent to the Nahran Omar laboratories of the Basrah Oil Company for the purpose of conducting chemical analysis using GC-MS.

3. Results and discussion

Physical and chemical properties

1- Temperature

Figure (1) shows the rate temperatures measured during the experiment period, it was noted that the highest temperature was 21.5C° on the twentieth day of the experiment and the lowest was 19.5 C° on the tenth and fortieth day of the experiment.

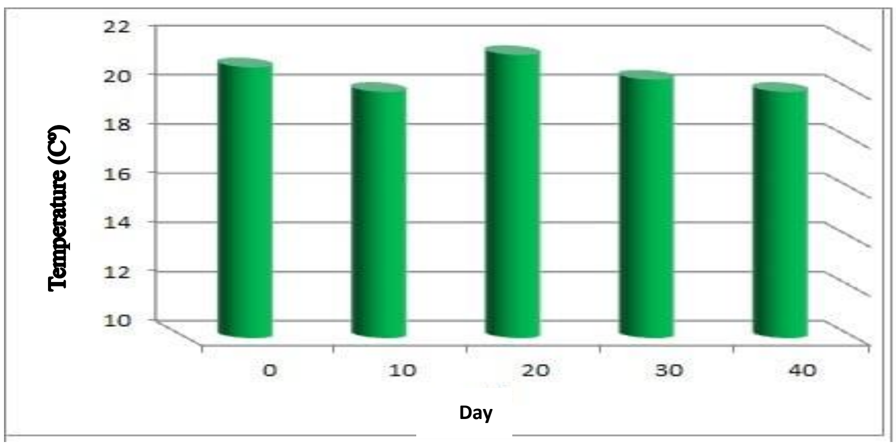

Figure (1): The rate air temperature

pH

Figure (2) shows the pH rate of soils contaminated with the different concentration of cadmium and lead elements for a plant *T. foenum- graecum* the highest was 6.50 in the treatment of the mixture at concentration 50ppm and the lowest 6.12 to treatment lead in concentration 10ppm compared the control sample, which had a pH of soil 6.74.

The statistical analysis showed that there were no significant differences at the level ($p< 0.05$).The reason for the low pH value may be attributed to the addition of cadmium and lead to soils of plant *T. foenum- graecum* these results are agreement with the study (AL-Jubouri, 1995), (Abu Dahl, 1999) and (AL-Jumaily and Rahi, 2000) who found that adding sulfur lowered the pH of the soil.

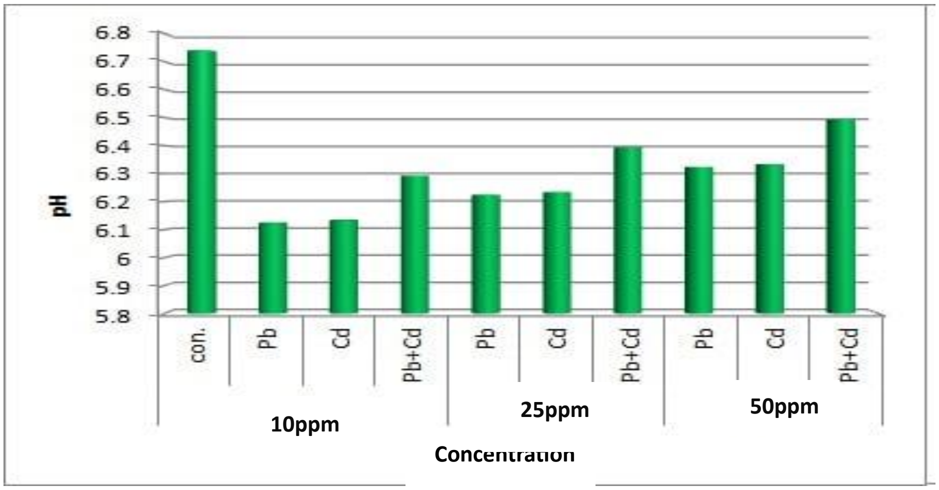

Figure (2): pH rate of soils contaminated with different concentrations of cadmium and lead for plants *T. foenum- graecum*

Salinity

Figure (3) shows the salinity rate of soils contaminated with different concentrations of cadmium and lead for plant *T. foenum-graecum*, and it was the highest 1.848 mg/L to treatment cadmium at concentration 50ppm and the lowest 0.884 mg/L in mixture treatment at concentration 10 ppm while the control sample whose salinity was 1.398 mg/L . The statistical analysis showed that there were no significant differences at the level ($p<0.05$). The reason for this may be attributed to the addition of cadmium and lead to the potting soil, which may increase the salinity of the soil, also carrying watering causes the accumulation of salts and the absence of organic matter in the potting soil led to high concentrations of salinity in it.

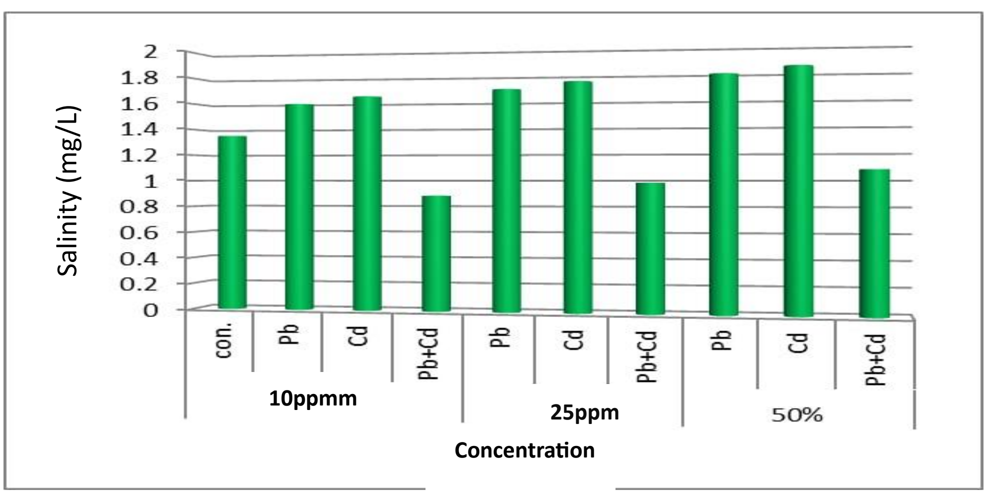

Figure (3): salinity rate for soils contaminated with different concentrations of cadmium and lead for plant *T. foenum- graecum*

Total organic carbon of soil

Figure (4) shows the total organic carbon rate for soil contaminated with different of cadmium and lead for plant *T. foenum- graecum* the highest was 0.06 g for the two treatments of cadmium, lead at both concentrations (25,50) ppm and the lowest 0.02 g at concentration50 ppm treatment the mixture compared with the control sample, which amounted to total organic carbon 0.05 g. The statistical analysis showed that there were significant differences at the level ($p<0.05$). The reason for this is that soil contamination with heavy metals leads to an increase in the total organic carbon in the soil (Shirdam *et al*., 2008).

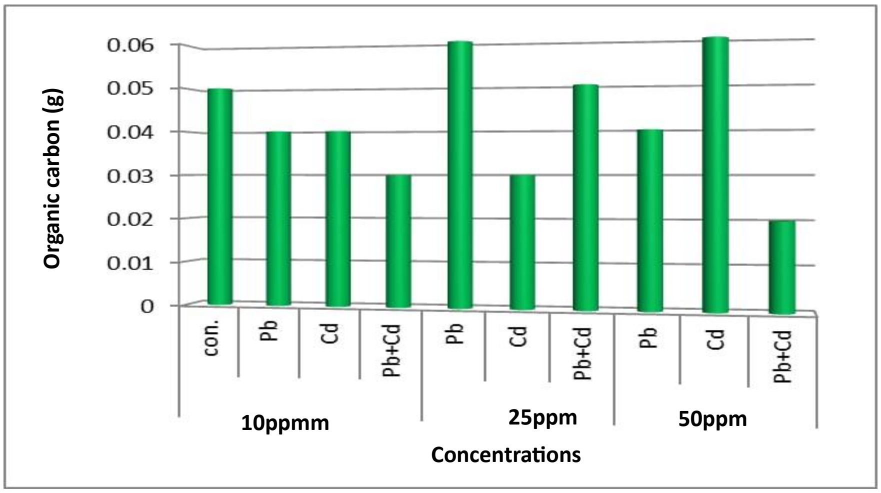

Figure (4): total organic carbon rate of soils contaminated with different concentrations of cadmium and lead for plant *T. foenum- graecum*

Plant examinations

Plant height

Figure (5) shows the rate of high plant *T. foenum- graecum* the highest was 7.3 cm to treatment cadmium on the tenth day of the experiment and the lowest 6.2 cm to treatment lead at the end of the experiment compared with the control sample which reached a plant height 8.6 cm. The statistical analysis showed that there were significant differences at the level ($p< 0.05$).The results show that the plant height was affected by heavy metals added to the soil the effect of the lead element is from the height of the plant, and the reason for this is due to the toxicity of the lead element it can affect the permeability of the plasma membrane, resulting in a decrease in the water content of cells especially, the interference of cadmium with the water balance was diagnosed(Costa and Morel, 1994).The toxicity of the cadmium element is a reason for the effect of plants, and stunting is one of the main and visible symptoms of cadmium toxicity(Moreno *et al*., 1999).

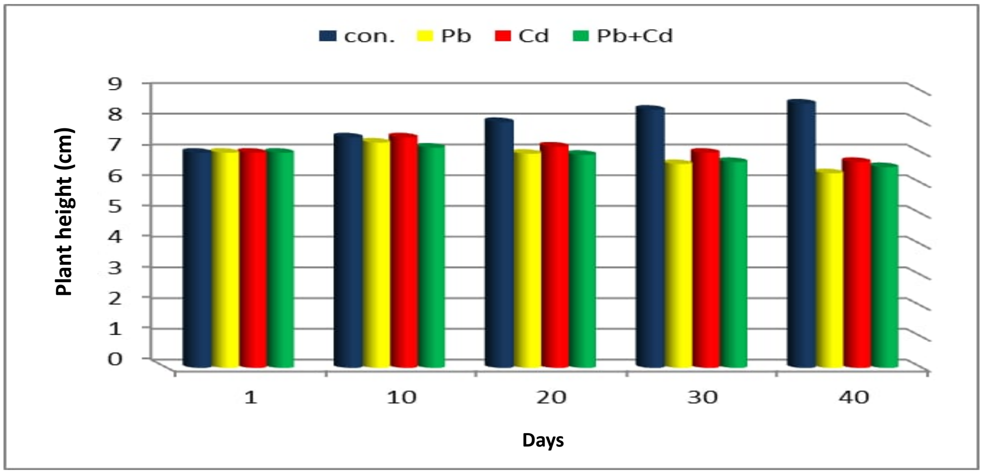

Figure (5): the rate of height of the plant *T. foenum- graecum* pollutant with different concentrations of cadmium and lead

2- Leaf length

Figure (6) shows the rate leaf length of plant *T. foenum- graecum* pollutant with different concentrations of cadmium and lead the highest was 1.34cm in treating cadmium at the beginning of the experiment, and the lowest was 0.98cm in treating the mixture at the end of the experiment compared to the control sample which the length of the leaf was 1.5 cm. The statistical analysis showed that there were significant differences at the level ($p < 0.05$). This effect may be attributed to the deterioration of the plasma membrane by heavy metals, which leads to a decrease in the absorption of nutrients, causing poor growth and a lack of leaf area.(Baccio *et al*., 2003).

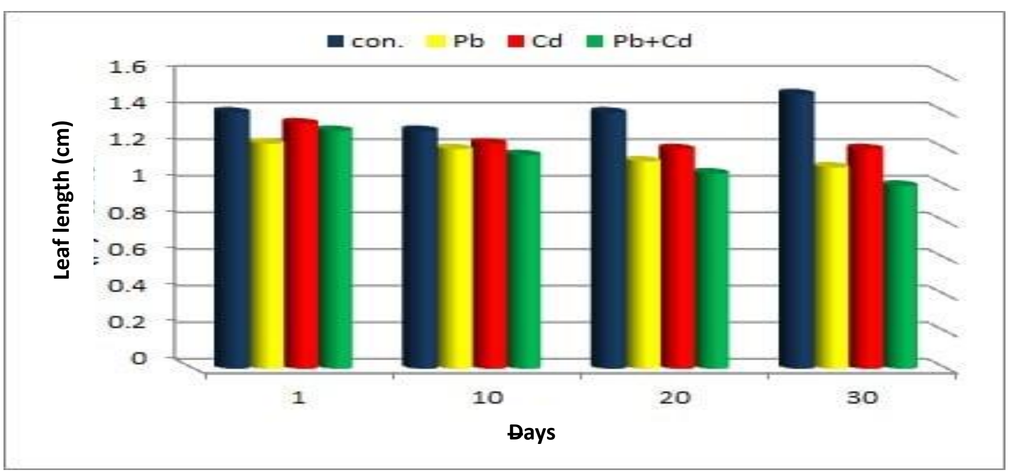

Figure (6): the rate leaf length of the plant *T. foenum- graecum* polluted with different concentrations of cadmium and lead

Total chlorophyll

Figure (9) shows the total chlorophyll rate of the plant *T. foenum- graecum* polluted with different concentrations of cadmium and lead the highest was 0.10405 mg/g in treated cadmium at the beginning of the experiment and the lowest was 0.0667 mg/g in treated cadmium on the 20th day of the experiment compared with the two control samples in which the total chlorophyll rate was 0.1256, 0133 mg/g. The statistical analysis showed that there were significant differences at the level ($p< 0.05$). The reason is that heavy metals have a toxic effect on plant leaf components, especially since the more cadmium is in the plant tissues, the less its content of chlorophyll is due to the inhibitory effect of cadmium on the work of the enzymes contributing to the chlorophyll synthesis process (Al-Mayah and Al- Assadi, 2012).

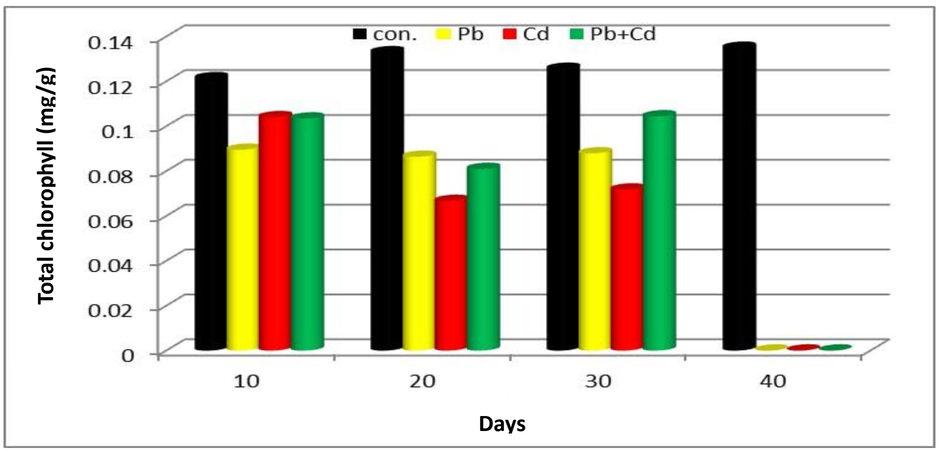

Figure (7): the total chlorophyll rate of the plan *T. foenum- graecum* polluted with different concentrations of cadmium and lead.

4-Carotene

Figure 10 showed the carotene rate of the plant *T. foenum- graecum* polluted with different concentrations of cadmium and lead the highest was 0.00395 mg/g in the cadmium treatment at the beginning of the experiment and the lowest was 0.00104 mg/g in the cadmium treatment on the twentieth day of the experiment compared with the two control samples whose carotene levels were 0.0042, 0.0041 mg/g. The statistical analysis showed that there were significant differences at the level ($p< 0.05$). This is because increasing the carotene content is a defensive strategy for plants to combat mineral stress. Some non-enzymatic antioxidants, including carotenoids, may play a role in the events of resistance to heavy elements by protecting the changeable macromolecules from the attack of free radicals that are formed during various metabolic reactions that lead to oxidative stress (Galli *et al*., 1996).

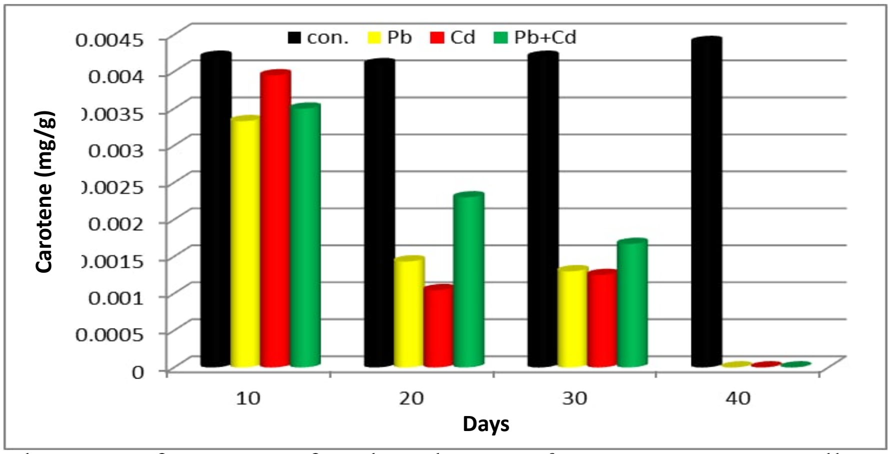

Figure (8): the rate of carotene for the plant *T. foenum- graecum* polluted with different concentrations of cadmium and lead.

5-Total organic carbon of plant

Figure (11) shows the total organic carbon of the plant *T. foenum- graecum* polluted with different concentrations of cadmium and lead, the highest was o.51 g for the cadmium treatment at 10 ppm and the lowest was 0.31g at 50 ppm for the mixture treatment compared to the control sample who's the total organic carbon was o.55g. The statistical analysis showed that there were significant differences at the level ($p< 0.05$).The reason for this may be attributed to the mineral stress that leads to an increase in the total organic carbon (Macoustra *et al*., 2015; Al-Asadi *et al*., 2022).

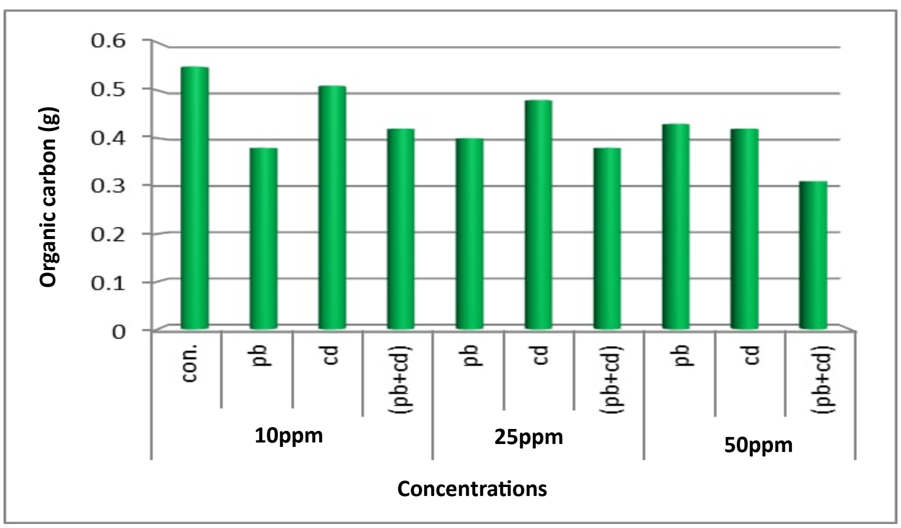

Figure (9): total organic carbon rate for the plant *T. foenum- graecum* Contaminated with different concentrations of cadmium and lead

Chemical compounds extracted in *T. foenum- graecum*

The number of active chemical compounds extracted from *T. foenum- graecum*

Figure (12) shows the number of active chemical compounds extracted from the plan *T. foenum- graecum* Contaminated with different concentrations of cadmium and lead, The number of chemical compounds extracted from the plant *T. foenum- graecum* varied according to the concentrations of cadmium and lead added, the number of compound diagnosed with GC-Mass technology in the control sample was 21 compounds the concentration of 50 ppm for the treatment of the mixture showed 41 compounds, followed by 36 compounds for the concentration of 25 ppm for the treatment of the mixture. The reason for this difference in the number of diagnosed compounds is due to the stress caused by adding heavy elements to plants, as they have a physiological reaction to protect the seeds from stress and increase their resistance against those heavy elements. The characteristic of the plant *T. foenum- graecum* it deals with seeds accordingly the plant takes the defensive role by producing many effective compounds which is a reaction to that increase in the concentration of heavy metals and thus works to prevent reaching them and make. (Al-Asadi *et al*., 2013).

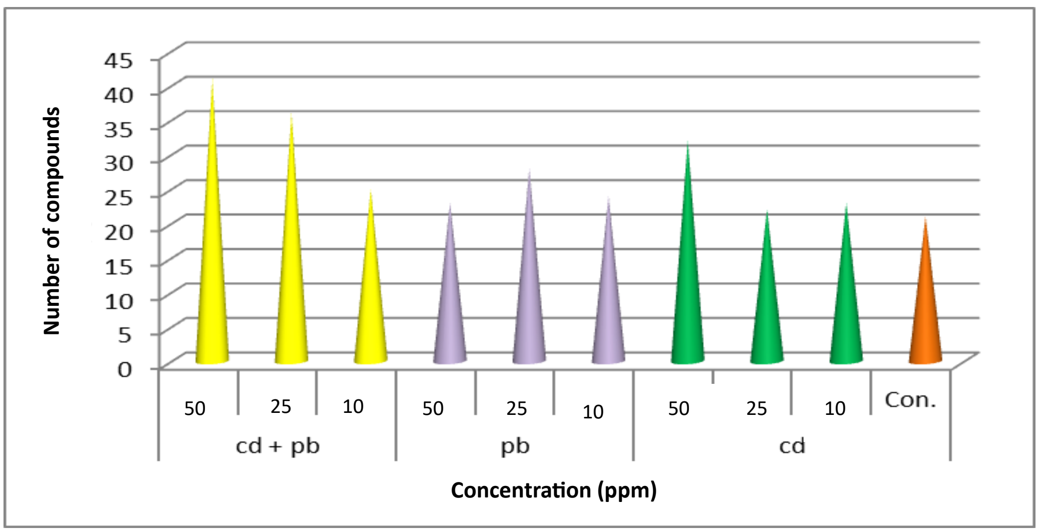

Figure (10): the number of active chemical compounds extracted from the plant *T. foenum- graecum* Contaminated with different concentrations of cadmium and lead

Percentages of active chemical compounds extracted from the plant *T. foenum- graecum*

Compound Ethyl Oleate

Ethyl Oleate is an aromatic compound of the ester group found in organic supplements (marjoram oil).It also one of the compounds that are used at present in the production of biofuels (Tapanes *et al*.,2003) by which extract from the plant of the barnacles J.tropha curcas (L.) it is a colorless oil although some samples may appear yellow it is regulated as a food additive in the United States by the Food and Drug Administration and is also used as a solvent for pharmaceutical preparations containing lipophilic substances such as steroids, lubricants and plasticizers (Laposata, 2010).

recorded the highest percentage of compound Ethyl Oleate which was 3.27% for the concentration 50 ppm to treat lead and the lowest percentage of the compound Ethyl Oleate which was 2.03% for the concentration 25 ppm to treat the mixture compared to the control sample, in which the percentage of the compound was 4.42%.

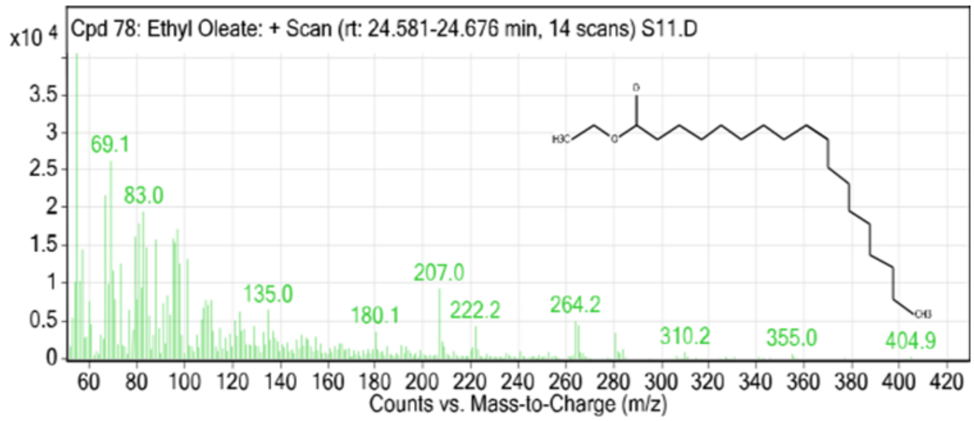

Figure (11): the chemical structure of the compound Ethyl Oleate in the plant *T. foenum- graecum*

Compound Cyclotrisiloxane, hexamethy

Cyclotrisiloxane, hexamethy of manufactured compounds used for cosmetic agents this compound does not occur naturally. recorded the highest percentage of compound Cyclotrisiloxane, hexamethy which was 7.17% for the concentration 25 ppm to treat the cadmium and the lowest percentage of the compound Cyclotrisiloxane, hexamethy which was 0.70% for the concentration 10 ppm to treat the mixture compared to the control sample, in which the percentage of the compound was 1.70%.

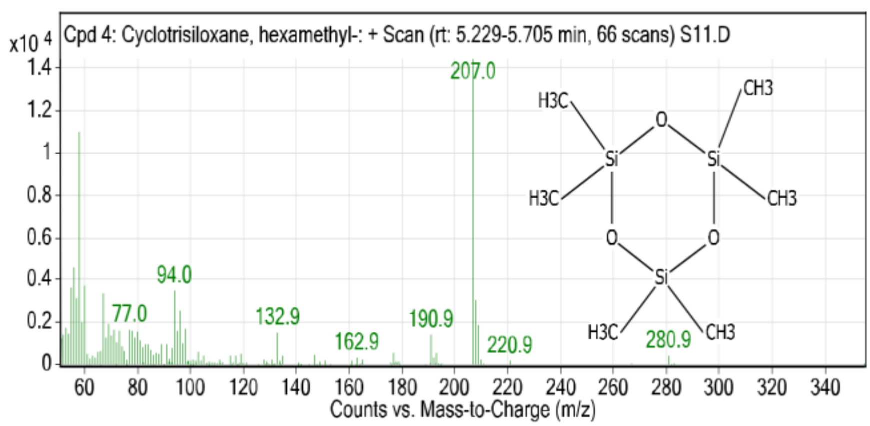

Figure (12): the chemical structure of the compound Cyclotrisiloxane, hexamethyl in the plant *T. foenum- graecum*

Compound Cyclotetrasiloxane, octamethyl

The compound Cyclotetrasiloxane, octamethyl is one of the compounds used in many different industries it causes its accumulation on various parts of the body such as the liver and the respiratory system, and this compound has not been isolated from nature. recorded the highest percentage of the compound Cyclotetrasiloxane, octamethyl which was 3.51% for the concentration 25 ppm to treat mixture while the lowest percentage was recorded for concentration 10ppm to treat cadmium was 1.82% compared with the control sample, which was the percentage 3.90%.

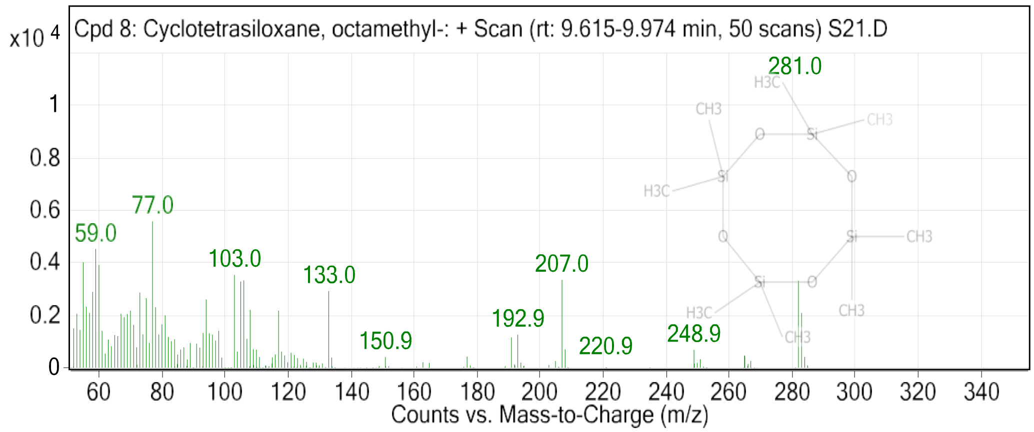

Figure (13): the chemical structure of the compound Cyclotetrasiloxane, octamethyl in the plant *T. foenum- graecum*

4- Compound Benzenemethanol,4-hydroxy-.alpha.-[1-methylamino)ethyl]-,(R*,S*)

ThecompoundBenzenemethanol,4-hydroxy-.alpha.-[1-(methylamino)ethyl]-(R*,S*) is one of the alkaloid compounds that have not been isolated so far from the natural world it is a compound that has the ability to increase the secretion of adrenaline in the synapsesm it is used as a stimulant and a bronchodilator, athletes use it as a stimulant to increase endurance in championship games, and it is also used with pain relievers to relieve cold symptoms by relieving airway congestion, which reduces the amount of mucus and facilitates breathing. recorded the highest percentage of the compound Benzenemethanol,4-hydroxy-.alpha.-[1-(methylamino)ethyl]-,(R*,S*)]- which was28.30% for the concentration 25ppm to treat lead, its lowest percentage was 14.22% for the concentration 50ppm to treat lead compared with the control sample, in which the percentage was 17.21%.

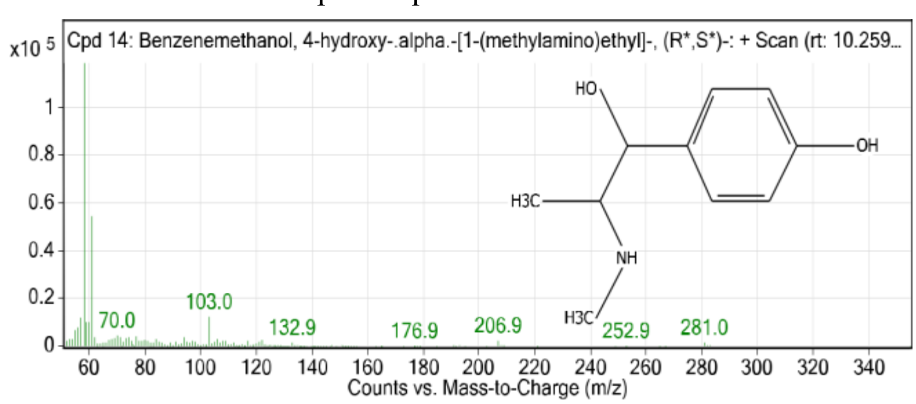

Figure (14): the chemical structure of the compound Benzenemethanol,4-hydroxy-.alpha.-[1-(methylamino)ethyl]-,(R*,S*) in *T. foenum- graecum*

5-Compound 2, 5-Octadecadiynoic acid, methyl ester

The compound 2, 5-Octadecadiynoic acid, methyl ester is among the derivatives of fatty acids, as it was diagnosed for the first time from the tea plant *Camellia sineensis* which is used in alternative medicine and in the treatment of infections. recorded the highest percentage of the compound 2, 5-Octadecadiynoic acid, methyl ester which was 23. 92% for concentration 10ppm to treat mixture, the lowest percentage was 3.23% for concentration 50ppm to treat mixture compared with the control sample in which the percentage was 6.06%.

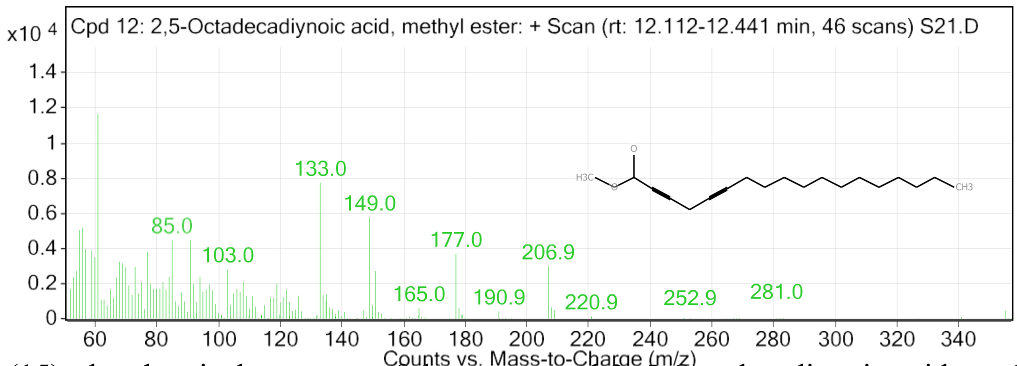

Figure (15): the chemical structure of the compound 2, 5-Octadecadiynoic acid, methyl ester in the plant *T. foenum- graecum*

6-Compound2, 7-Diphenyl-1,6-dioxopyridazino[4,5;2',3'] pyrrolo[4',5'-d]pyridazine

The compound 2,7-Diphenyl-1,6-dioxopyridazino[4,5;2',3'] pyrrolo[4',5'-d]pyridazine one of the alkaloids isolated from the plant Datura (L.) recorded the highest percentage of the compound 2,7-Diphenyl-1,6-dioxopyridazino[4,5;2',3'] pyrrolo[4',5'-d]pyridazine which was 0.76%for concentration 25ppm to treat cadmium and the lowest percentage, which was 0.52% for concentration10ppm to treat lead compared with the control sample in which the percentage was 1.27%.

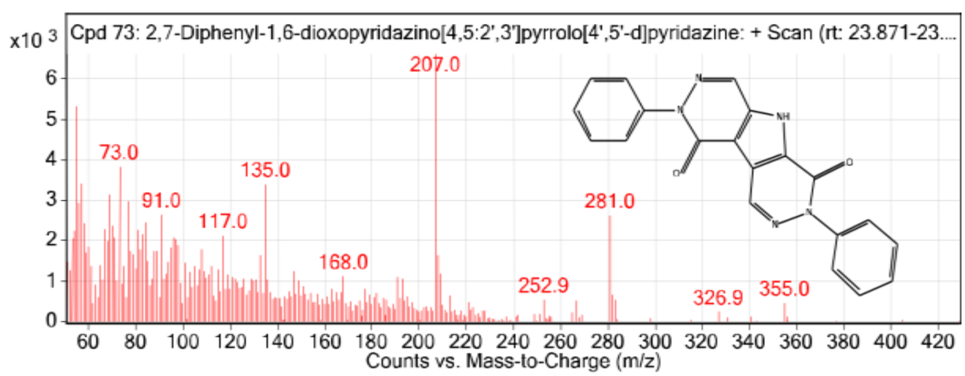

Figure (16): the chemical structure of the compound 2, 7-Diphenyl-1,6-dioxopyridazino[4,5;2',3'] pyrrolo[4',5'-d]pyridazine in the plant *T. foenum- graecum*

7- Compound Phen-1, 4-diol, 2, 3-dimethyl-5-trifluoromethyl

The compound Phen-1, 4-diol, 2, 3 -dimethyl-5-trifluoromethyl- of the benzoide compounds Trifluoromethylbenzenes isolated from the leaves of the wild celery plant Apium graveolens (L.). Appendix (1) recorded the highest percentage of the compound Phen-1, 4-diol, 2,3-dimethyl-5-trifluoromethyl which was 4.50% for concentration 50ppm to treat lead and the lowest percentage 0.33% for concentration 25ppm to treat mixture compared with the control sample, which was the percentage 1.84%.

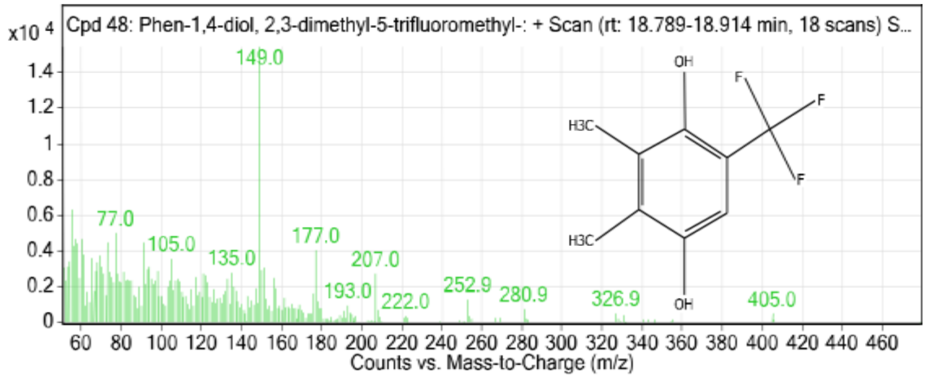

Figure (17): the chemical structure of the compound Phen-1, 4-diol, 2, 3-dimethyl-5-trifluoromethyl in the plant *T. foenum- graecum*

8-Compound 1-Ethynyl-3, trans (1,1-dimethylethyl)-4,cis-methoxycyclohexan-1ol

The compound1-Ethynyl-3,trans (1,1-dimethylethyl)-4,cis-methoxycyclohexan-1ol was first found in the plant Cassia angustifolia, it is one of the compounds that are included in the composition of many medicinal drugs, such as drugs antifungal (Candidiasis) and in anti- inflammatory. recorded the highest percentage of the compound 1-Ethynyl-3,trans(1,1-dimethylethyl)-4,cis-methoxycyclohexan-1ol which was 22.77% for concentration 10ppm to treat lead and the lowest percentage 1.01% for concentration 50ppm to treat mixture compared with the control sample, which was the percentage 7.69%.

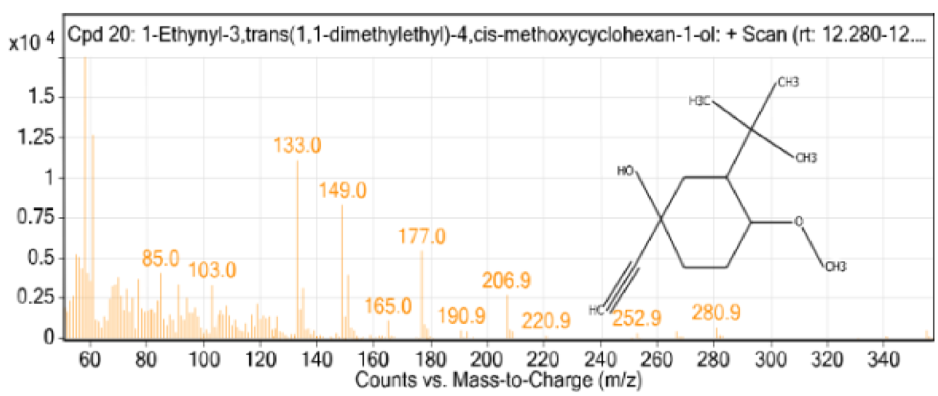

Figure (18): the chemical structure of the compound 1-Ethynyl-3, trans (1,1-dimethylethyl)-4,cis-methoxycyclohexan-1ol in the plant *T. foenum- graecum*

9-CompoundAcetamide,N-methyl-N-[4-(3-hydroxypyrrolidinyl)-2-butynyl]-

The compound Acetamide, N-methyl-N-[4-(3-hydroxypyrrolidinyl)-2-butynyl] belongs to the class of organic compounds known as alpha-amino acids and their derivativatives. recorded the highest percentage of the compound Acetamide, N-methyl-N-[4-(3-hydroxypyrrolidinyl)-2-butynyl] which was 3.30% for the concentration 25ppm to treat lead and the lowest percentage 0.25% for the concentration 50ppm to treat mixture compared with the control sample, which was the percentage 4.73%.

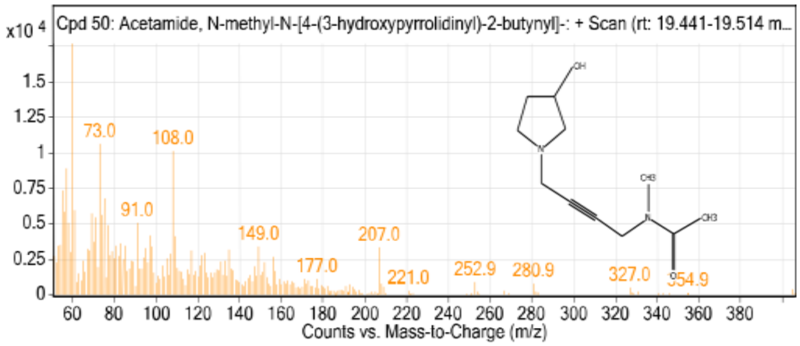

Figure (19): the chemical structure of the compoundAcetamide,N-methyl-N-[4-(3-hydroxypyrrolidinyl)-2-butynyl]- in the plant *T. foenum- graecum*

10-Compound Hexadecenoic acid, ethyl ester

The compound Hexadecanoic acid, ethyl ester is the fatty acid derivative that has been identified in rice, vanilla and several fatty acid esters and other plants are also considered a colorless solid that has a wax-like odor and does not dissolve in water and is used as an agent for conditioning hair and skin. recorded the highest percentage of the compound Hexadecanoic acid, ethyl ester which was 5.64% for concentration 50pppm to treat mixture and the lowest percentage 1.29% for concentration 10ppm to treat lead compared with the control sample, which was the percentage 3.54%.

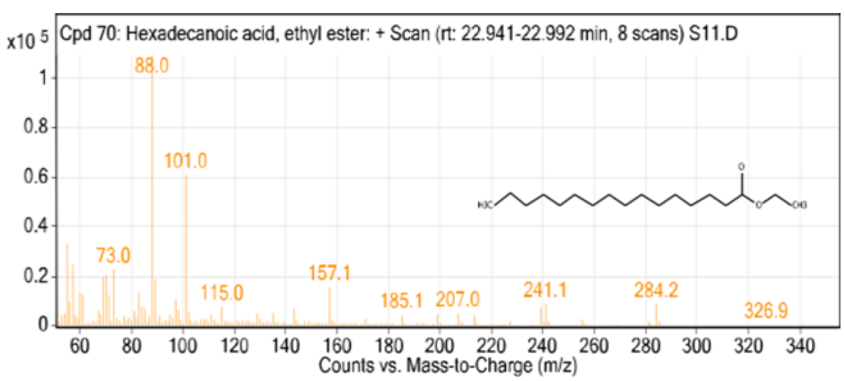

Figure (20): the chemical structure of the compound Hexadecenoic acid, ethyl ester e in the plant *T. foenum- graecum*

11-Compund Methyl 10, 11-tetradecadienoate

The compound Methyl 10,11-tetradecadienoate is an important starting compound for both natural and synthetic organic synthesis, it is a colorless liquid that is insoluble in water, but it can be produced in oils and is a precursor of steroids in plants and it is a flavoring component and included as an additive to cigarettes (Jooj *et al*., 2009). recorded percentage 1.847% for concentration 50ppm for treat lead and 0.145% for concentration 25ppm to treat mixture.

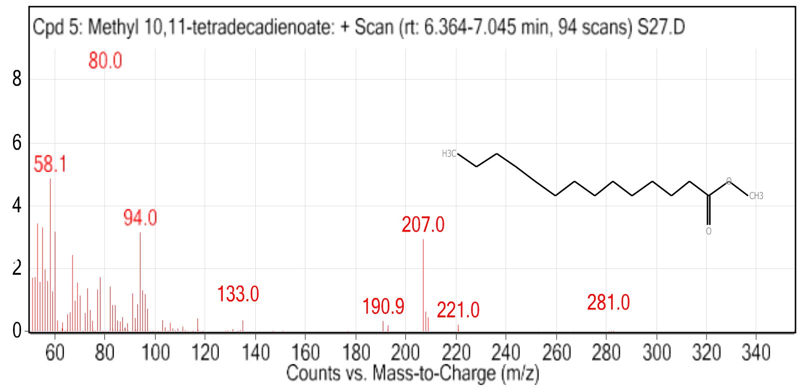

Figure (21): the chemical structure of the compound Methyl 10, 11-tetradecadienoate in the plant *T. foenum- graecum*

Conclusions

The study revealed that lead had a greater impact on T. foenum-graecum compared to cadmium. Additionally, the contamination with these elements influenced the quantity of chemical compounds present in the plant, with the effective compounds decreasing in the polluted treatments compared to the control treatment. T. foenum-graecum's ability to accumulate heavy metals makes it a crucial indicator of pollution.

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التأثير السام للرصاص والكادميوم على الصفات المظهرية والتشريح والكيميائية لنبات *Trigonella foenum-graecum*

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المستخلص

هدفت الدراسة الحالية إلى التحقيق في تأثير الكادميوم والرصاص على الخصائص الظاهرية والفسيولوجية لنبات *Trigonella foenum-graecum* L. في التربة ذات التركيزات المتفاوتة لهذين العنصرين .بالإضافة إلى ذلك، فحص تأثير الكادميوم والرصاص على المركبات الكيميائية النشطة في النبات ووظيفتها الطبية .تضمنت التجربة زراعة بذور النباتات ومراقبتها لمدة سبعة أشهر، من تشرين الثاني 2020 إلى مايو 2021تم تسجيل الملاحظات والنتائج بعد تعريض النباتات لتركيزات مختلفة10) ، 25 ، 50 جزء في المليون (من الكادميوم والرصاص وخليط من العنصرين .وسجل أعلى مستوى ملوحة قدره 1.848 ملغم/لتر في التربة المعالجة بتركيز 50 جزء في المليون من الكادميوم، في حين لوحظ أدنى مستوى ملوحة قدره 0.884 ملغم/لتر في التربة المعالجة بخليط بتركيز 10 جزء في المليون .أسفرت المعالجة بمزيج من الكادميوم والرصاص بتركيز 50 جزء في المليون عن أكبر عدد من المركبات الكيميائية النشطة، حيث تم اكتشاف 41 مركبا، بينما أظهرت المعالجة الضابطة أقل عدد من المركبات النشطة، مع تحديد 21 مركبا.

الكلمات الدالة: الكادميوم، الرصاص، الحلبة، *Trigonella foenum-graecum*، الملوثات.