ISSN: 2458-8989

Natural and Engineering Sciences

NESciences, 2024, 9 (3): 163-176 doi: 10.28978/nesciences.1606578

Assessment of Heavy Metals Phytotoxicity on Seed Germination and Seedling Growth of Tomato Plants *(Solanum Lycopersicum L.)*

Nisreen J. Razak [1*], Mohammed H. Abass [2] and Khairullah M. Awad [3]

[1*] Plant Protection Department, Agriculture College, University of Basrah, Iraq.
E-mail: nisreenjafar@yahoo.com

[2] Plant Protection Department, Agriculture College, University of Basrah, Iraq.
E-mail: mohammed.alkinany@uobasrah.edu.iq

[3] Date Palm Research Centre, University of Basrah, Iraq. E-mail: khearallah.awad@uobasrah.edu.iq

Abstract

This study has been designed to examine the effects of heavy metals, specifically cobalt (Co), chromium (Cr), cadmium (Cd), and lead (Pb), on the germination indices and growth of different tomato varieties (*Solanum lycopersicum* L.). The current findings revealed that all investigated heavy metals had a significant and detrimental impact on both germination indices and growth parameters at laboratory and greenhouse conditions, with Cd and Pb exhibiting the most pronounced effects. In comparison to the control treatment, the germination percentage decreased by 74.66 and 81.56% when exposed to Pb (380 $mg.L^{-1}$) in laboratory and greenhouse conditions, respectively. Additionally, the germination time was extended two-folds the duration under Cd and Pb treatments. Pb exhibited a significant impact on the reduction of both hypocotyl and radicle lengths in emerging seedlings, at decrease levels of 51.40 and 59.02%, respectively, compared to the control treatment. The results also indicated that Cd (16 $mg.L^{-1}$) had the most pronounced effect on the growth parameters of tomato seedlings cultivated in potting soil under greenhouse conditions, although there was no significant difference observed when compared to Pb. The plant lost more than half of its height, as well as 69% of its shoot FW, 68% of its shoot DW, 70% of its root FW, and 74% of its root DW. Now that we know these things, we need to clean up the heavy metal trash that comes from farms. Taking better care of the land and using methods that lessen the effects of metals is one way to improve plant health and long-term production.

Keywords:

Cadmium, hypocotyl, lead, radicle, sensitivity.

Corresponding Author: Nisreen J. Razak, E-mail: nisreenjafar@yahoo.com

Article history:

Received: 07/08/2024, Revised: 26/09/2024, Accepted: 25/10/2024, Available online: 31/12/2024

Introduction

They stay in the body for a long time and tend to build up in live things. They hurt and kill animals and plants too (Al-Aradi et al., 2020). There are too many dangerous metals in farmlands, which is a problem for everyone. The issue comes from various places, including base rock, garbage dumps with solid or liquid waste, mineral fertilisers, pesticides, farming supplies, workplace fumes, and pollution in cities (Ahmed et al., 2023). There are two kinds of heavy metals: those that are needed for life and those that are not. Heavy metals like Fe, Cu, Mn, Cr, and Co are needed by living things, but they only need small amounts most of the time. Heavy metals like lead, cadmium, and mercury are bad for living things and don't need to be there because they aren't known to do any good (Ali et al., 2019).

Heavy metals that plants don't need can change how they use amino acids and other nutrients, how gases move between plants, how proteins are activated, and how photosynthesis works over time (Seneviratne et al., 2019). When seeds sprout and when plants grow are very important parts of a plant's life journey. In places where foods can grow, stronger seeds help them do better, which pays off in the long run (Baruah et al., 2019).

A lot of people in Iraq and around the world grow a plant called the tomato, or Solanum lycopersicum L. It's a Solanaceae plant. It's important because it's good for you, feels good, and helps the business (Mustafa et al., 2021). Not only that. In the southern part of Iraq, in the Basrah Governorate, there are a lot of tomato plants (Veerasamy & Fredrik, 2023). Heavy metals are released into the air here by many factories, especially those that make oil and burn natural gas (Gabash et al., 2024). This makes it hard to live. Heavy metals like Pb and Cd make tomato plant seeds and babies grow more slowly (Baruah et al., 2019; Bingol et al., 2023).

There has never been a study of how heavy metals affect the rate at which tomato plants in Basrah, in the southern part of Iraq, sprout and grow young. This study was done to find out how sensitive different kinds of tomatoes are to heavy metals. It looked at how metals affect the growth of seeds and plants in a garden and a lab (Thirunavukkarasu et al., 2024).

Materials and Methods

The current study took place in the University of Basrah's Agriculture College yard and labs during the growing season of 2023–2024. Five types of tomatoes were chosen: "8565," "Jihan," "Salimah," and "Yassamen." A 10% sodium hypochlorite solution was used to kill any bacteria that could have hurt the plants or come in the way of our treatment (Al-Jashaami et al., 2024). This was done for 15 minutes. After that, three times of clean, pure water was used to wash them (Khyade, 2019).

Experimental Treatments

Four drinks with heavy metals were made and used as medicines in this study. One of them had 35 mg of cobalt (Co) in it. Cd (Cd) at 16 mg and L^{-1} in the form of CoC_{l2}.Chrome (Cr) in the form of CdC_{l2} at 150 $mg.L^{-1}$ in the form of CrC_{l3} and 380 mg of lead (Pb).L^{-1} in the form of $Pb(CH_3COO)^2$, and a group that got nothing but water as a reference. The heavy metal numbers came from a study that hasn't been made public yet.

Laboratory Experiment

In the lab, a 9-cm circle Petri dish was used. It had three groups of ten clean seeds of each kind. On the filter paper, two milliliters of each heavy metal treatment were put. The paper was then left to soak. We chose to cover the Petri plates so that not too much water would drain out of them. The temperature was 25±1°C and the humidity was 65% for ten days. Every day and every 24 hours, the growth rate and other things were checked. The last growth rates were written down after 10 days of being kept in a warm place.

Pot Experiment

Heavy metals like cadmium, lead, cobalt and cobalt were used to test how different types of tomatoes react. Pot trails were set up in a yard. The soil had an electric conductivity (Ec) of 12.33 ds.m-1, 1.56% organic matter, and a action exchange capacity of 8.28 cmole.kg^{-1}. The earth had a pH of 7.03. Ten of each type of seed was put into a pot with one kilogram me of soil. One heavy metals solution was put into each of the three pots as a safety measure until the field could hold more. Three of each type of pot and five of each drink were used for each test. After 10 days, growth factors are used to check how healthy the plant is. After 45 days, growth factors are used to check how well it worked.

Germination Indices

The following germination indices were measured on the 10th day of the laboratory and pot experiments, according to (Ranal & De Santana, 2006).

1. $Germination\ percentage\ (\%) = \frac{\text{seeds germinated}}{\text{total seeds}} * 100$

2. $Germination\ speed = \frac{n1}{d1} + \frac{n2}{d2} + \frac{n3}{d3} + \cdots \dots \dots \dots . + \frac{n10}{d10}$

   Where, n =number of germinated seeds, d=number of days.

3. $mean\ germination\ time\ (MGT) = \sum f.x / \sum f$

   Where $f.x$ seeds germinated on day x.

4. $Mean\ germination\ daliy\ (MGD) = \frac{\text{Total number og germinted seeds}}{\text{Total number of days}}$

5. $Peak\ value\ (PV) = \frac{\text{Highest seed germintaed}}{\text{Number of days}}$

6. $Germination\ value\ (GV) = PV * MDG$

Growth Parameters

A metric tool was used to measure the plant's height from the ground to its peak. We measured the radicle and hypocotyl of seeds that had grown in Petri plates in centimeters as well. The weight of the stems and plants was split into two groups: weight when they were fresh and weight when they were dry. Weighing was done on the plants. The buds and stems were dried at 70°C for 72 hours on a TE 2148 Sartorius electronic scale. Then, their new weights were put down. After that, the dry mass weights of the plants were found. Grammes were used to find out how much the fresh and dry goods weighed.

Statistical Analysis

Five different kinds of tomatoes were used in the study. Juhan, Salimah, Asma, and 8565 were these people. Five treatments were also used. One was a control, and the other four were heavy metal treatments (Co, Cr, Cd, and Pb). We used SPSS-24 software (SPSS In., Chicago, IL, USA) to divide the information into two groups and look at the differences between them. Three times were given for each test. The LSD was used to find changes between means that were important from a statistical point of view. If the P number was less than 0.05, the difference was statistically important.

Results

Heavy Metals Toxicity on Germination Indices of S. Lycopersicum Seeds Under Laboratory Condition

The toxicity of examined heavy metals on seed germination indices of several varieties of *S. lycopersicum* plant under laboratory conditions were obvious as illustrated in Table 1. As general mean of all studied varieties, the highest germination percentage (GP) was 97.33% in the control group, which indicates that the majority of seeds successfully germinated in such conditions. When Co was added, the germination percentage decreased significantly to 64.99%, which indicates a moderate negative effect on the ability of seeds to germinate. Cr showed a similar effect with a GP of 62.59%. Cd had the greatest effect in reducing the GP compared than Co and Cr, as the value decreased to two and half folds (34.00%), while Pb had the most negative effect, as the GP decreased to 24.66, which indicates that Pb had the greatest effect in reducing the ability of seeds to germinate compared to the rest of the metals.

Germination Speed Index (GS) results show that in the control treatment the GS was 2.36, which indicates that the seeds germinated relatively quickly without the presence of heavy metals. When Co or Cr were added, the GS value decreased more than tow-folds and reached 1.06 and 0.99, respectively, without significance variation. Which indicates a moderate slowdown in the germination speed. Cd reduced the germination speed even more; the GS value dropped to 0.40, while Pb had the most negative effect; the GS value recorded a minimum of 0.28, which indicates a significant slowdown in the germination speed up to ten-folds compared to control one.

MGT (mean germination time) index was used to measure the effect of heavy metals on the germination time of *S. lycopersicum* seeds. As is known, the MGT value reflects the required average time for seeds to germinate; the larger the value, the longer the time required for seed germination, In the control group, the MGT value was 4.58, which indicates that the seeds took a moderate time to germinate without the presence of heavy metals. When Co and Cr were added, the MGT value increased to 6.60 and 6.54, respectively, which indicates that both metals similarly slow down the germination process. When Cd and Pb were added, the MGT value increased further to 8.68 and 8.38, respectively, indicating that these two metals had a greater negative effect on delaying the germination process than Co and Cr.

In terms of the mean germination daily (MGD) index, the results showed a significant reduction when seed exposed to heavy metals compared to control group. In the Control, the value of MDG was 0.97, which indicates that the seeds were germinating at a constant rate and close to the maximum per day under natural conditions. When Co was added, the value decreased to 0.64, which indicates a moderate slowdown in the Daily germination rate. Cr showed a similar effect with an MDG value of 0.62; whereas Cd further reduced the Daily germination rate to 0.34, while the Pb had the most negative effect, as the MDG value decreased to 0.24, which shows that Pb had the greatest effect in reducing the Daily germination rate compared to the rest of the coefficients. Heavy metals treatments affected significantly peak value (PV) index; the highest PV index was calculated in the control group (1.05), while it reduced to 0.42, 0.17, 0.38, and 0.13 when seeds treated with Co, Cd, Cr, and Pb, respectively. The highest germination Value (GV) Index was calculated in the control group (1.02); this average significantly decreased in seeds incubated with heavy metals and amounted to 0.28, 0.06, 0.24 and 0.03 for Co, Cd, Cr and Pb metals, respectively, the results showed that Cd and Pb were more influential in reducing the value of this index. The results of the statistical analysis showed that all the examined varieties did not differ among themselves significantly in the studied germination indices.

Table 1. Heavy metals toxicity on the germination indices of five varieties of Solanum lycopersicum L. under laboratory conditions

Variety	Treatment	GP	GS	MGT	MDG	PV	GV
Asma	Control	100.00	2.51	4.36	1.00	1.33	1.33
	Co	70.00	1.13	6.29	0.70	0.55	0.39
	Cd	33.33	0.40	8.50	0.33	0.13	0.04
	Cr	63.33	0.97	6.71	0.63	0.39	0.24
	Pb	20.00	0.21	9.50	0.20	0.11	0.02
Jihan	Control	100.00	2.39	4.53	1.00	1.00	1.00
	Co	66.66	0.99	7.04	0.66	0.35	0.23
	Cd	30.00	0.33	9.11	0.30	0.15	0.04
	Cr	69.66	1.19	5.88	0.69	0.44	0.29
	Pb	23.33	0.27	8.55	0.23	0.13	0.03
Salimah	Control	90.00	2.09	4.63	0.90	0.83	0.75
	Co	68.33	1.38	5.72	0.68	0.58	0.42
	Cd	36.66	0.46	7.91	0.36	0.24	0.09
	Cr	56.66	0.94	6.30	0.56	0.37	0.21
	Pb	30.00	0.33	9.00	0.30	0.19	0.05
Yassamen	Control	96.66	2.28	4.57	0.96	1.08	1.04
	Co	56.66	0.86	6.75	0.56	0.32	0.18
	Cd	40.00	0.47	8.55	0.40	0.20	0.08
	Cr	73.33	1.15	6.66	0.73	0.46	0.34
	Pb	20.00	0.26	5.75	0.20	0.08	0.02
8656	Control	100.00	2.54	4.83	1.00	1.00	1.00
	Co	63.33	0.92	7.19	0.63	0.31	0.19
	Cd	30.00	0.32	9.33	0.30	0.15	0.05
	Cr	50.00	0.71	7.17	0.50	0.25	0.12
	Pb	30.00	0.33	9.11	0.30	0.16	0.05
Average of factors							
Varieties							
Asma		57.33	1.04	7.07	0.57	0.50	0.40
Jihan		57.93	1.03	7.02	0.57	0.41	0.32
Salimah		56.33	1.04	6.71	0.57	0.44	0.30
Yassamen		57.33	1.01	6.46	0.57	0.43	0.33
8656		54.66	0.96	7.52	0.54	0.37	0.28
Heavy metals							
Control		97.33	2.36	4.58	0.97	1.05	1.02
Co		64.99	1.06	6.60	0.64	0.42	0.28
Cd		34.00	0.40	8.68	0.34	0.17	0.06
Cr		62.59	0.99	6.54	0.62	0.38	0.24
Pb		24.66	0.28	8.38	0.24	0.13	0.03
LSd (0.05) for varieties and treatments		5.49	0.10	0.80	0.05	0.08	0.08

Heavy Metals Toxicity on Seedlings Growth of S. Lycopersicum Plants Under Laboratory Condition

The results of Table 2. show the effect of heavy metals on hypocotyl length (HL) of *S. lycopersicum* seedlings. The results revealed that the HL of seedlings in the control group was 2.84 cm. When Co or Cr were added to the media, the HL increased slightly but not significantly compared to the control treatment; it was reached 2.86 and 2.89, respectively. On the other hand, Cd and Pb significantly reduced the HL to 1.60 and 1.38 cm, respectively. Pb had the highest negative effect than Cd, as the presence of Pb in the growth media led to a reduction of HL by 51.40%, while the presence of cadmium led to a reduction of 43.66%.

Similar trend of results was observed in Table 3. which shows the effect of heavy metals on the radicle length (RL) of *S. lycopersicum* seedlings. The results indicated that all examined heavy metals had a negative effect, as they significantly reduce the growth of the RL compared to the control. The RL in the control group was 1.44 cm, a reduction to 1.25 was seen in Co; Cd to 0.70; Cr to 1.22 and Pb to 0.59 cm. It is noted from the results that Pb had the most negative effect, as its presence in the growth media led to a reduction in RL by 59.03% compared to the control, while the presence of Co, Cr and Cd led to a reduction by 13.19, 15.27 and 51.38, respectively.

Table 2. Heavy metals toxicity on the hypocotyl length (HL)/ cm of five varieties of Solanum lycopersicum L. under laboratory conditions

Variety	Hypocotyl length (HL)/ cm in Treatments					Average of variety
	Control	**Co**	**Cd**	**Cr**	**Pb**	
Asma	3.22	3.86	1.59	3.52	1.55	2.75
Jihan	2.59	2.4	1.31	2.33	0.91	1.91
Salimah	2.76	3.00	1.71	2.84	1.49	2.36
Yassamen	2.68	2.32	1.86	2.43	1.66	2.19
8656	2.94	2.74	1.54	3.33	1.32	2.37
Average of treatment	2.84	2.86	1.60	2.89	1.38	
LSd (0.05) for varieties and treatments= 0.27						

Table 3. Heavy metals toxicity on the radicle length (RL)/ cm of five varieties of Solanum lycopersicum L. under laboratory conditions

Variety	Radicle length (RL)/ cm in Treatments					Average of variety
	Control	**Co**	**Cd**	**Cr**	**Pb**	
Asma	1.78	1.59	0.93	1.35	0.83	1.29
Jihan	1.43	1.17	0.80	1.20	0.28	0.977
Salimah	1.83	1.23	0.60	1.11	0.60	1.07
Yassamen	1.05	1.27	0.63	1.20	0.62	0.953
8656	1.12	1.00	0.55	1.23	0.61	0.902
Average of treatment	1.44	1.25	0.70	1.22	0.59	
LSd (0.05) for varieties and treatments= 0.10						

Heavy Metals Toxicity on Germination Indices of S. Lycopersicum Seeds Under Greenhouse Conditions

The results of Table 4 show the effect of heavy metals on the germination indices of seeds of five *S. lycopersicum* varieties under greenhouse conditions. The results indicated that there was a significant variation in the GP among different treatments. The control treatment recorded the highest germination rate of 94%, which indicates the healthiness of the seeds and their suitability for the environmental conditions. In the Co treatment, the plant grew more slowly (72.66%), and in the Cd treatment, it grew even more slowly (37.33%). The Cr effect was another one that could be seen 53.33% of the time. 17.33% of the plants that were given PB did not grow. This was the very low number that was seen. It was 81.56% less GP when the Pb was used instead of the control. Heavy metals can change how hard it is to grow S. lycopersicum seeds and slow their growth.

The GS scores make it very clear that the two ways are not at all the same. It was the group with 2.25 people that had the most people. But this was clear for Co since it lowered the GS number to 1.37. It was worse than the Cr effect, which was 0.90 times stronger at 0.47 times. The method that used lead got the worst score from this index. Different types of heavy metals can hurt the growth of S. lycopersicum seeds in different ways. This metal makes it hard for the seeds to grow at first.

We can also see that the MGT, or average germination time, is not stable. The MGT index number for the control group was 4.67, which shows how quickly seeds grow in the wild. When the Co was added, though, it went up to 5.76. In other words, the plants grew less quickly than when they were given the safe medicines. There was more Cd, so it took longer for the seeds to grow (8.20). Also, the MGT number was higher after the Cr treatments than it was at the beginning, when it was 6.27. When lead was used, the MGT number was 9.46 most of the time. Pb and other heavy metals, like those found in this study, make it take longer for S. lycopersicum seeds to grow. When the MGT score is high, it takes longer for the seeds to grow. In other words, the metals stop the seeds from growing in the first place.

The mean germination daily (MDG) number is different for each method, as shown in Table 4. When it came to the MDGs, there was no difference between the groups. Co came next with a score of 0.72, and Cr came next with a score of 0.53. It went down even more when Cd was added, to 0.37. If pb's MDG index number is less than 0.17, it means that it had the most significant effect on the seed's growth rate. This study found that heavy metals slow down the growth of seeds. This is why less seed grows every day when the MDG index number is low. Heavy metals do change how fast seeds grow, as this shows.

You can see that the PV changes a lot from one treatment to the next. A PV index number of 0.88 showed that the treatment that didn't change was the most useful. The seeds grew the fastest when they did that. But the Co treatment got only a 0.51, which means that not as many seeds grew there as in the base treatment. It fell even more when Cr was present, and the number that was found was 0.35. The number 0.11 made it clear that Pb was the worst. For Cd, on the other hand, the PV number was 0.18. Heavy metals make it so that plants can't grow as fast as they would like to. Why does this take place? It takes longer for growth to hit its peak when the PV index number is low. These metals make it harder for seeds to grow the way they should.

Statistics show that there are many GVs for each way. More seeds grew in the group that wasn't touched (GV score = 0.84). But the Co treatment got a 0.37, which means it did not grow as much as the non-co treatment. It fell even more when Cr was present, and the number that was found was 0.18. The second bad thing was that Cd was 0.07. With a score of 0.02, lead was the most dangerous type.

Heavy Metals Toxicity on Seedlings Growth of S. Lycopersicum Plants Under Greenhouse Condition

Five types of S. lycopersicum plants grown in pots in a greenhouse are shown in Table 5 to show how heavy metals affected their growth. We measured the plant's height, shoot fresh weight (SFW), shoot dry weight (SDW), root fresh weight (RFW), and root dry weight (RDW).

The obtained results showed that the application of heavy metals using Co, Cd, Cr, and Pb exerted a negative effect on *S. lycopersicum* plant height. The control treatment recorded the highest plant height, measuring 19.97 cm. In turn, applied Co, reduced significantly the height of the plant to 12.63 cm, which indicates a moderate negative effect on growth. The treatment of Cr was more negative than Co, which reduced the plant height significantly to 10.93 cm. The most pronounced negative effects were observed with Cd and Pb treatments, which resulted in reduction of plant heights up to two-folds compared to control and reached 6.57 cm and 6.97 cm, respectively, with no significant difference.

Regarding the results of shoot fresh weight (SFW), the control treatment recorded the highest SFW, amounting to 643.52 mg. While, all treatments with heavy metals showed a significant decrease in this parameter. Cd and Pb had the most negative effect, recording 197.97 and 223.25 mg, respectively, with no significant difference between them. The effect of Cr was also significantly negative, with a weight of 347.38 mg, while Co recorded 384. 57 mg. This reflects that Cr had a significantly greater effect than Co.

The results of shoot dry weight (shoot DW) were in the same trend as the shoot FW, which all heavy metals treatments led to a significant reduction in this parameter compared to the control treatment. Cd and Pb had a greater negative impact than Co and Cr. In addition to that Cr had a greater negative impact than Co. The value of the Shoot DW in the control treatment was 59.09 mg, which decreased significantly to 37.63, 18.68, 31.96 and 21.51 mg, when treated with Co, Cd, Cr and Pb, respectively.

The results showed that the studied heavy metals had a negative effect on the root fresh weight (RFW) of tomato plants. The RFW of the control group amounted to 47.92 mg. Treatment with Co led to a significant reduction to 30.32 mg, and 26.24 mg in Cr treatment. The results show that the treatment with Cd was the most negative in the effect, as the RFW reached 14.22 mg, but without a significant difference with Pb treatment, which recorded 15.51 mg.

The results of the effect of heavy metals on the RDW were consistent with the results of the RFW parameter. Treatment with Co, Cd, Cr, and Pb significantly reduced the value of this parameter from 8.64 in the Control to 5.37, 2.19, 4.27, and 2.49, respectively. The results indicate that Cd had a greater negative impact compared to other metals.

Table 4. Heavy metals toxicity on the germination indices of five varieties of Solanum lycopersicum L. under greenhouse conditions

Variety	Treatment	GP	GS	MGT	MDG	PV	GV
Asma	Control	100.00	2.72	4.367	1.00	1.11	1.11
	Co	73.33	1.56	5.103	0.73	0.47	0.34
	Cd	33.33	0.39	8.833	0.33	0.13	0.05
	Cr	53.33	1.00	5.600	0.53	0.44	0.23
	Pb	16.66	0.18	9.667	0.17	0.11	0.02
Jihan	Control	96.66	2.29	4.547	0.97	0.87	0.83
	Co	70.00	1.03	7.167	0.70	0.35	0.25
	Cd	33.33	0.44	7.833	0.33	0.15	0.05
	Cr	53.33	0.72	7.677	0.53	0.26	0.14
	Pb	16.66	0.18	9.333	0.17	0.11	0.02
Salimah	Control	100.00	2.32	4.733	1.00	0.92	0.92
	Co	76.66	1.74	4.740	0.77	0.83	0.64
	Cd	50.00	0.67	7.600	0.50	0.25	0.12
	Cr	56.66	1.03	5.743	0.57	0.38	0.21
	Pb	16.66	0.17	9.667	0.17	0.11	0.02
Yassamen	Control	90.00	1.88	5.110	0.90	0.65	0.59
	Co	76.66	1.35	5.963	0.77	0.43	0.33
	Cd	36.66	0.45	8.140	0.37	0.20	0.08
	Cr	53.33	0.81	6.857	0.53	0.28	0.15
	Pb	23.33	0.26	9.167	0.23	0.12	0.03
8656	Control	83.33	2.01	4.607	0.83	0.89	0.76
	Co	66.66	1.20	5.873	0.67	0.47	0.31
	Cd	33.33	0.39	8.610	0.33	0.17	0.06
	Cr	50.00	0.95	5.477	0.50	0.39	0.21
	Pb	13.33	0.14	9.500	0.13	0.11	0.01
Average of factors							
Varieties							
Asma		55.33	1.16	6.714	0.55	0.45	0.35
Jihan		54.00	0.93	7.311	0.54	0.34	0.25
Salimah		60.00	1.18	6.497	0.60	0.49	0.38
Yassamen		56.00	0.95	7.047	0.56	0.33	0.23
8656		49.33	0.93	6.813	0.49	0.40	0.26
Heavy metals							
Control		94.00	2.25	4.67	0.94	0.88	0.84
Co		72.66	1.37	5.76	0.72	0.51	0.37
Cd		37.33	0.47	8.20	0.37	0.18	0.07
Cr		53.33	0.90	6.27	0.53	0.35	0.18
Pb		17.33	0.19	9.46	0.17	0.11	0.02
LSd (0.05) for varieties and treatments		5.15	0.08	0.88	0.05	0.07	0.06

Table 5. Heavy metals toxicity on the growth parameters of five varieties of Solanum lycopersicum L. under greenhouse conditions

Variety	Treatment	Plant height/ cm	Shoot FW/ mg	Shoot DW/ mg	Root FW/ mg	Root DW/mg
Asma	Control	16.17	521.05	48.16	38.80	7.00
	Co	10.33	303.05	30.78	24.80	4.47
	Cd	5.17	166.52	15.39	12.40	2.20
	Cr	9.67	311.56	28.8	23.20	3.18
	Pb	6.33	199.13	18.86	14.2	2.30
Jihan	Control	18.17	585.51	55.25	43.60	7.87
	Co	12.83	390.62	38.22	30.80	5.10
	Cd	6.17	198.75	18.37	12.80	2.03
	Cr	11.50	370.65	33.25	27.60	4.68
	Pb	7.00	205.61	20.85	14.80	2.67
Salimah	Control	22.83	735.92	68.01	54.80	9.88
	Co	13.50	415.11	40.21	32.40	5.84
	Cd	7.67	247.10	20.35	15.40	2.32
	Cr	11.50	355.65	32.25	27.60	3.98
	Pb	6.83	200.24	22.84	18.40	2.41
Yassamen	Control	19.33	623.12	57.59	46.40	8.37
	Co	12.33	377.51	36.74	29.60	5.34
	Cd	7.00	225.61	20.85	16.80	2.45
	Cr	11.17	359.9	33.26	26.80	4.83
	Pb	8.50	243.96	23.5	18.40	2.95
8656	Control	23.33	752.03	66.45	56.00	10.10
	Co	14.17	436.59	42.2	34.00	6.13
	Cd	6.83	220.24	18.45	13.70	1.96
	Cr	10.83	339.16	32.27	26.00	4.69
	Pb	6.17	198.75	21.5	15.40	2.15
Average of varieties						
Asma		9.53	300.26	28.39	22.68	3.83
Jihan		11.13	350.22	33.18	25.92	4.47
Salimah		12.47	390.80	36.73	29.32	4.88
Yassamen		11.67	366.02	34.38	27.27	4.78
8656		12.27	389.39	36.17	29.02	5.00
Average of treatments						
Control		19.97	643.52	59.09	47.92	8.64
Co		12.63	384.57	37.63	30.32	5.37
Cd		6.57	197.97	18.68	14.22	2.19
Cr		10.93	347.38	31.96	26.24	4.27
Pb		6.97	223.25	21.51	15.51	2.49
LSD (0.05) for varieties and treatments		0.80	25.93	2.39	1.93	0.34

Discussion

In the present study, the effect of heavy metals Co, Cd, Cr, and Pb on germination indices and early seedling growth of *S. lycopersicum* was investigated. The results obtained showed that these metals have adverse effects on the percentage of germination (GP), germination speed (GS), mean germination time (MGT), mean daily germination (MDG), peak value (PV) and germination value (GV) under laboratory and greenhouse conditions.

The inhibition and delayed in seed germination of Cd and Pb were greater than Co and Cr, generally, the effect of heavy metals on seed germination could be attributed to two factors, firstly, due to their direct toxicity, and secondly, their ability to prevent the seed absorption of water (Kranner & Colville, 2011). Pb ions may be interfering with seed enzymes linked to the mobility and hydrolysis of food reserves, such as proteins and carbohydrates, which are essential for embryo metabolism and growth (Osman & Fadhlallah, 2023). This would account for the suppression of germination observed in the current results. The reduction of seed germination caused by metals has been linked to several disruptions in the germination metabolism chain of events, according to studies on *Vicia sativa* (common vetch) and *Vicia faba* (faba bean) (Muccifora & Bellani, 2013; Rahoui et al., 2008).

The generation of energy is necessary for the germination of seeds, and its hindrance affects the synthesis of proteins, RNA, and DNA since these activities require energy (Moosavi et al., 2012). Consequently, low seed viability resulting from the developing embryo's reduced capacity to produce energy in response to heavy metal, in particular Cd and Pb may be the cause of observed fall in GP.

Our findings are consistent with those of (Baruah et al., 2019), who found that Pb and Cd inhibited the germination of wheat, pea, and tomato seeds and that Pb is more harmful to seed germination than Cd. Also (Hafiz & Ma, 2021) found that presence of Cr in growth media of forty-five tomato genotypes reduced germination percentage and delayed germination in more 90% of examined genotypes compared to control. The results of the (Bingol et al., 2023) study also confirmed that Cd at a concentration of 40 ppm led to a reduction in the germination percentage of tomato seeds by 83% compared to control treatment (Yaqvob et al., 2011).

It was also found that all of the heavy metals applied significantly decreased the seedlings radicle length. Radicle length reduction was in the order Pb>Cd>Cr>Co. Although Co and Cr did not significantly affect the hypocotyl length, the treatment with Cd and Pb significantly reduced it by 43.66 and 51.40%, respectively. According to (Hafeez et al., 2023) metal stress causes an inhibition of meristematic cell development decrease the functions of the hydrolytic enzymes amylase and protease, which reduces radicle and hypocotyl length, particularly radicle. Cd and Pb may inhibit growth promoters largely by preventing enzyme activation and reducing or directly inhibiting cell division by interfering with the integrity of the cell membrane. This might explain the inhibitory impact of metals on cell expansion and division (Genchi et al., 2020).

When the heavy metals (Co, Cd, Cr, and Pb) were added, the results showed a pronounced negative effect on the overall growth of the tomato plant (plant height and plant biomass). Toxic effect of heavy metals on tomato growth was as follow: Cd, Pb, Cr and Co. In plants, heavy metals interfere with many chemical processes and impede enzymatic activity. However, the reduction in the plant growth due to Cd and Pb was greater than Co and Cr, which may be ascribed to the Cd and Pb ability to affect plant metabolism as well as ability to affect the formation of new cells (Zeeshan et al., 2020). The negative effect of heavy metals on the growth parameters of tomato plants has already been reported in some previous studies (Baruah et al., 2019; Bingol et al., 2023).

Conclusion

Based on the results, it can be concluded that the addition of heavy metals such as Cobalt (Co), chromium (Cr), cadmium (Cd), and lead (Pb) to the agricultural growing environment negatively and significantly affects the seed germination and growth of the tomato plant. Experiments has shown that these metals led to inhibit and delay the seed germination, as well as a pronounced decrease in plant height, along with reduction in the fresh and dry weight of both the shoot and root parts. Therefore, care should be taken when handling these metals in agricultural systems to avoid reducing crop productivity.

Author Contributions

All Authors contributed equally.

Conflict of Interest

The authors declared that no conflict of interest.

References

Ahmed, D. A. E. A., Slima, D. F., Al-Yasi, H. M., Hassan, L. M., & Galal, T. M. (2023). Risk assessment of trace metals in Solanum lycopersicum L. (tomato) grown under wastewater irrigation conditions. *Environmental Science and Pollution Research, 30*(14), 42255–42266. https://doi.org/10.1007/s11356-023-25157-8

Al-Aradi, H. J., Al-Najjar, M. A., Awad, K. M., & Abass, M. H. (2020). Combination effect between lead and salinity on anatomical structure of date palm phoenix dactylifera L. Seedlings. *Agrivita*, *42*(3), 487–498. https://doi.org/10.17503/agrivita.v42i3.2511

Ali, H., Khan, E., & Ilahi, I. (2019). Environmental chemistry and ecotoxicology of hazardous heavy metals: environmental persistence, toxicity, and bioaccumulation. *Journal of chemistry, 2019*(1), 6730305. https://doi.org/10.1155/2019/6730305

Al-Jashaami, S. H. K., Almudhafar, S. M., & Almayahi, B. A. (2024). The Impact of Climatic Characteristics on Increasing Soil Salinity in Manathira District Center. *Natural and Engineering Sciences*, *9*(2), 426-440. https://doi.org/10.28978/nesciences.1574447

Baruah, N., Mondal, S. C., Farooq, M., & Gogoi, N. (2019). Influence of Heavy Metals on Seed Germination and Seedling Growth of Wheat, Pea, and Tomato. *Water, Air, and Soil Pollution, 230*(273). https://doi.org/10.1007/s11270-019-4329-0

Bingol, Ö., Battal, A., & Erez, M. E. (2023). The Effects of Cadmium Concentrations on Germination and Physiological Parameters in Tomato (Solanum lycopersicum Lam.). *Journal of Agricultural Production, 4*(2), 111–116. https://doi.org/10.56430/japro.1365163

Gabash, H. M., Resan, A. Z., Awad, K. M., Suhim, A. A., & Abdulameer, A. H. (2024). Biochemical Responses of Date Palm Phoenix dactylifera L. to Combined Stress of Salinity and Nickel. *Basrah Journal of Agricultural Sciences*, *37*(1), 236–246. https://doi.org/10.37077/25200860.2024.37.1.18

Genchi, G., Sinicropi, M. S., Lauria, G., Carocci, A., & Catalano, A. (2020). The Effects of Cadmium Toxicity. *International Journal of Environmental Research and Public Health, 17*(11), 3782. https://doi.org/10.3390/ijerph17113782

Hafeez, A., Rasheed, R., Ashraf, M. A., Qureshi, F. F., Hussain, I., & Iqbal, M. (2023). Effect of heavy metals on growth, physiological and biochemical responses of plants. *In Plants and Their Interaction to Environmental Pollution* (pp. 139–159). Elsevier. https://doi.org/10.1016/B978-0-323-99978-6.00006-6

Hafiz, M. F., & Ma, L. (2021). Effect of chromium on seed germination, early seedling growth and chromium accumulation in tomato genotypes. *Acta Physiologiae Plantarum*, *43*(100). https://doi.org/10.1007/s11738-021-03267-5

Khyade, V.B. (2019). Efficiency of Mulberry, Morus alba (L) as fodder for cattle. *International Academic Journal of Innovative Research*, *6*(1), 77–90. https://doi.org/10.9756/IAJIR/V6I1/1910007

Kranner, I., & Colville, L. (2011). Metals and seeds: Biochemical and molecular implications and their significance for seed germination. *Environmental and Experimental Botany*, *72*(1), 93–105. https://doi.org/10.1016/j.envexpbot.2010.05.005

Moosavi, S. A., Gharineh, M. H., Tavakkol Afshari, R., & Ebrahimi, A. (2012). Effects of Some Heavy Metals on Seed Germination Characteristics of Canola (Barassica napus), Wheat (Triticum aestivum) and Safflower (Carthamus tinctorious) to Evaluate Phytoremediation Potential of These Crops. *Journal of Agricultural Science*, *4*(9), 11–19. https://doi.org/10.5539/jas.v4n9p11

Muccifora, S., & Bellani, L. M. (2013). Effects of copper on germination and reserve mobilization in Vicia sativa L. seeds. *Environmental Pollution, 179*, 68–74. https://doi.org/10.1016/j.envpol.2013.03.061

Mustafa, A. A., Abass, M. H., & Awad, K. M. (2021). Responses of three tomato (Lycopersicon esculentum L.) varieties to different salinity levels. *Plant Cell Biotechnology and Molecular Biology, 22*(41 & 42), 277-291.

Osman, H. E., & Fadhlallah, R. S. (2023). Impact of lead on seed germination, seedling growth, chemical composition, and forage quality of different varieties of Sorghum. *Journal of Umm Al-Qura University for Applied Sciences*, *9*(1), 77–86. https://doi.org/10.1007/s43994-022-00022-5

Rahoui, S., Chaoui, A., & Ferjani, E. El. (2008). Differential sensitivity to cadmium in germinating seeds of three cultivars of faba bean (Vicia faba L.). *Acta Physiologiae Plantarum, 30*(4), 451–456. https://doi.org/10.1007/s11738-008-0142-x

Ranal, M. A., & De Santana, D. G. (2006). How and why to measure the germination process? *Revista Brasileira de Botanica, 29*(1), 1–11. https://doi.org/10.1590/S0100-84042006000100002

Seneviratne, M., Rajakaruna, N., Rizwan, M., Madawala, H. M. S. P., Ok, Y. S., & Vithanage, M. (2019). Heavy metal-induced oxidative stress on seed germination and seedling development: a critical review. *Environmental Geochemistry and Health*, *41*(4), 1813–1831. https://doi.org/10.1007/s10653-017-0005-8

Thirunavukkarasu, T. C., Thanuskodi, S., & Suresh, N. (2024). Trends and Patterns in Collaborative Authorship: Insights into Advancing Seed Technology Research. *Indian Journal of Information Sources and Services*, *14*(1), 71–77. https://doi.org/10.51983/ijiss-2024.14.1.4004

Veerasamy, K., & Fredrik, E. J. T. (2023). Intelligence System towards Identify Weeds in Crops and Vegetables Plantation Using Image Processing and Deep Learning Techniques. *Journal of Wireless Mobile Networks, Ubiquitous Computing, and Dependable Applications*, *14*(4), 45-59. https://doi.org/10.58346/JOWUA.2023.I4.004

Yaqvob, M., Golale, A., Masoud, S., & Hamid, R. G. (2011). Influence of different concentration of heavy metals on the seed germination and growth of tomato. *African journal of environmental science and technology*, *5*(6), 420-426.

Zeeshan, M., Ahmad, W., Hussain, F., Ahamd, W., Numan, M., Shah, M., & Ahmad, I. (2020). Phytostabalization of the heavy metals in the soil with biochar applications, the impact on chlorophyll, carotene, soil fertility and tomato crop yield. *Journal of Cleaner Production*, *255*, 120318. https://doi.org/10.1016/j.jclepro.2020.120318