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RESEARCH PAPER

Effects of Lead and Nickel on Seed Germination and Vegetative Growth on some Fabaceae Species

Sargul A. Khudhur[1], Ikbal M. Albarzinji[1]
[1] Department of Biology, Faculty of Science and Health, Koya University, Koya KOY45, Kurdistan Region – F.R. Iraq

A B S T R A C T:

This study aimed to assess the effects of nickel (Ni) and lead (Pb) as heavy metal elements on seed germination and seedling growth of three fabaceae tree species; *Gleditsia triacanthos Leucaena leucocephala* and, *Robinia pseudoacacia*. Each of Ni and Pb were applied as $NiCl_2$ and $PbCl_2$ at variegated concentrations viz., 0, 15, 30 and 45 mg.Kg^{-1} soil for each salt and their interactions under field conditions. The results showed that neither Ni nor Pb had a significant effect on the percent of *G. triacanthos* seeds germination, whereas, plant leaf area significantly increased at Ni15 and Ni30, P15, P30, and P45 while not significantly affected other vegetative growth characters as compared to the control treatment. For *L. leucocephala* it seemed to be more tolerant to the increasing Ni and Pb metals concentrations. For *R. pseudoacacia* Ni application cause a significant increase for plant height for all treatments, and root dry matter percent, nodules number at both Ni30, Ni45, whereas Pb application causes a significant increase in plant leaf area. No root nodules were seen in G. triacanthos species. From the results, it seen that the inhibition caused by Ni and Pb elements was rely on the element concentration, kind of metal, and the species of plant. Results indicated that low levels of nickel chloride is necessary for plant growth, while, increasing the concentrations of nickel chloride inhibited seed germination, and plant growth and may cause toxicity, yet the tolerance efficiency depends on the species of the plant. As conclude all studied species were affected by Ni and Pb that were added to soil which reflects on seed and seedling performance. *L. leucocephala* was more tolerant to Ni and Pb heavy metals compared to two other species, and high concentrations especially the 45 mg.kg^{-1} had more effects on the studied characteristics. In respect to this study results, it suggested that *L. leucocephala* had the best heavy metal tolerance reactions, so it is recommended to cultivating this species in that areas contaminated with heavy metals especially nickel and lead round Iraq and Kurdistan regions.

KEY WORDS: Lead, Nickel, *Gleditsia triacanthos*, *Leucaena leucocephala*, *Robinia pseudoacacia*
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1.INTRODUCTION :

The subject of heavy metals nowadays has received the care of scientists in the world, due to their risky effects on human health and the plant. The toxicity of heavy metals includes making the biomolecules inactive either by blocking the essential functional groups or by displacement of the essential metal ions (Nyiramigisha, 2021).
Zn, Cu, and Ni in low concentrations are considered micronutrients or essential elements, and it is necessary for plants growth.

Organic contaminants biodegradation inhibited in soils polluted with toxic metals, which also cause risks to humans and the ecosystem by polluting soil, water, and food, increasing desertification and many other problems (Kumari and Amarnath, 2021and Álvarez, et al., 2019). Soil is the media for seed germination, survival and plants growth. Nowadays, most soisoilsl are polluted by numerous materials like Ni and Pb as heavy metals, which decrease soil fertility, limit plant growth, and affects crop yields (Deswal and Laura, 2018).

Lead (Pb) is one of the highly toxic heavy metals, also called protoplasmic poison and it is a hazardous pollutant for the environment

* **Corresponding Author:**
Sargul A. Khudhur
E-mail: sargul.khudur@koyauniversity.org
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(Mehboob, et al., 2018). Although it is not one of the essential elements for plants, it is found accumulated in different parts of the plants and effects negatively on different physiological processes, such as seed germination inhibition, delays seedling growth, chlorosis, photosynthesis, cell death at high concentrations level (Fazal, 2015, and Sharma and Dubey, 2005). Nickel (Ni^{2+}) at low concentration is an essential micronutrient element for seed germination and normal plant growth. It becomes toxic at high concentrations in the soil and plants. At toxic levels it affects many biochemical and physiological processes in the plants (Amjad, *et al*., 2020).

The mechanisms of root for uptake Ni and Pb is mainly done by a passive diffusion and/or active transport depending on the plant species, acidity of soil, exist of other metals in addition to the concentration of Ni^{2+} in the soil solution, whereas Pb is generally taken up by passive diffusion, mostly through intercellular spaces of the apoplast, following the water movement within the plant (Kun, et al., 2021; Joseph, et al.,2018, and Abdel Aziz, et al., 2014).

G. triacanthos, *L. leucocephala*, and *R. pseudoacacia* plant species are planted as landscape in Iraqi Kurdistan region, they are important for carbon restoration, soil stabilization and landfills and wastelands re-vegetation, also in biotherapy. These plants produce high levels of biomass, grow rapidly, easily cultivated, and most importantly, tolerate and can accumulate high level concentrations of heavy metals in their aboveground parts.

The aims of this study were to test the effects of Ni and Pb elements as soil polluted heavy metals on some characteristics regarding the morphology and physiology of *G. triacanthos*, *L. leucocephala, and R. pseudoacacia* as three forest tree species belong to fabaceae family.

2. MATERIALS AND METHODS

2.1. Plant Materials and Growth Condition

Three tree species of fabaceae family: *L. leucocephala*, *R. pseudoacacia*, and *G. triacanthos* were classified by Dr. Serwan T. Al-dabbagh, Field Crops and Medicinal Plants Dept., College of Agricultural Engineering Sciences, Salahaddin University – Erbil. The healthy legume seeds (Figure 1) were collected from the campus of Koya University, Iraqi Kurdistan Region on 25th of March 2021. The mature pods were collected directly from 10 years aged with straight bales and well-formed trees by climbing them manually.

At a private field in Koya city located at 44^o38 E, $36\ ^o4$N and 570 m of altitude above sea level, a factorial experiment with a complete randomized design with three replications were used for each species to study the effects of concentrations (0, 15, 30 and 45 $mg.kg^{-1}$ soil) of two heavy metals nickel chloride ($NiCl_2$) and lead chloride ($PbCl_2$) and their interactions on each species separately.

Seeds were soaked in ordinary water at room temperature for 24 hours as described by Hamad and Anwer (2021). The planting of seeds were done using black polyethylene bags (sized 10x10x 30 cm) filled with 3 kg of loamy soil that well mixed with the required concentrations of $NiCl_2$ or $PbCl_2$ which were denoted as (Ni_0, Ni_{15}, Ni_{30} and Ni_{45}) for the first salt and (Pb_0, Pb_{15}, Pb_{30} and Pb_{45}) for the second salt respectively, with their interactions. Each experimental unit consists of 10 polyethylene bags. After seed establishment, three healthy seedlings (2.5 cm in length) were maintained. The pots were kept outside in the field (Table 1) and the pots were watered when needed with tap water to provide a possible uniform soil moisture conditions. 3 months after seed germination, samplings were prepared for taking the following characteristics:

(A)	(B)	(C)

Figure 1. Seeds of (A) *G. triacanthos, (B) L. leucocephala* and *(C) R. pseudoacacia* species.

Table 1. The maximum and minimum temperatures, the relative humidity and the amount of rainfall during the growing season (2021) *

Month	Air Temperature (C^o)		Relative Humidity(%)		Rain fall (mm)
	Maximum	Minimum	Maximum	Minimum	
March	26	4	83	29	24.3
April	39	10	85	18	9.6
May	43	19	50	16	4.3
June	47	22	38	13	0.0
July	48	25	29	12	0.0
August	48	23	33	14	0.0
September	45	22	35	15	0.0
October	39	13	67	18	0.0

* Agro-Meteorological Station in Koya city.

2.2 Studied Characteristics

Ahmadloo et al. (2012) described the rate of seed germination (G), as is shown below:

$$G(\%) = \frac{L}{S} * 100 \quad \text{where:}$$

G(%)= Germination percentage, L = Number of planted seed, S= Total number of emerged seedlings

Ranal and Santana (2006) expressed a formula for the velocity of germination as following:

$$M(\text{days}) = \sum_{i=1}^{n} N_i G_i \,/ \sum_{i=1}^{n} G_i$$

Where: M: velocity of germination (in days), G: seedlings number that emerged on the day of remark, N: number of days that counted since the day of sowing until the day of remark.

2.2.2. Vegetative Growth

Included the height of plant, numbers of leaves, leaf area of plant which were estimated by using the image j software as declared in Martin (2013). Stem and root diameter were measured using vernier caliper. Lengths of roots and nodules number were measured as it stated by Abdul (2009). Shoot, root and nodules of dry matter were measured as it mentioned in Al-Sahaf (1989).

2.3. Statistical Analysis

The study was conducted according to a Factorial Complete Randomized Design (F_2-CRD) for each plant species as individual experiment. Kind of the salt was the first factor, and the concentration of salts was the second factor. Each treatment was replicated three times and ten bags were considered as an experimental unit. Treatment means were compared by the analysis of variance test (ANOVA) using the SAS statistical program. The test of Duncan`s multiple range ($\alpha \leq 0.05$) was used for comparing between treatment means (Al-Mohammadi and Al-Mohammadi, 2002).

3. RESULTS AND DISCUSSIONS

3.1. Effects of nickel, lead and their interactions on seed performance and some vegetative growth of *G. triacanthos*

From the results shown in Table (2) it was found that neither Ni or Pb or their interactions had a significant effects on the percent of *G. triacanthos* seeds germination, whereas the seeds were germinated earlier with increasing Ni and Pb concentrations compared to no Ni or Pb plants, while the germination velocity decreased at Ni and Pb 45. Also for the interactions where the control treatment seeds emerged later (47.9 days) significantly compared to all other interactions except the treatment Ni30Pb15. For the vegetative growth parameters, we saw that the control treatment did not differ significantly with the treated plants for plant height, diameter of stem and the percent of shoot and root dry matter, Plant leaf area significantly increased at bot Ni15, Ni 30 as compared to control while decreased significantly at Ni 45. The results were agree with that of Ahmad, et al.,(2009), whom established that Ni concentrations at low levels promoted significantly sunflower seed germination and improved the growth of seedling, fresh and dry weights of germinating seeds, plumule and length of radicle, while higher concentrations caused a significant inhibition in seeds germination. Regarding Pb effects on the studied vegetative growth characteristics, it is found that it had no significant effects on each of stem diameter, plant leaves number, and the percent of shoot and root dry matter content, whereas increasing Pb concentration to 45 $mg.kg^{-1}$ decreased plant height significantly to 27.2 cm compared to 31.4 and 29.5 cm for the 15 $mg.kg^{-1}$ and the plants that not received Pb element. Using Pb at 15 $mg.kg^{-1}$ concentration increased plant leaf area significantly to 21.9 cm^2, whereas increasing the concentration to 30$mg.kg^{-1}$ and 45$mg.kg^{-1}$ decreased this parameter, which is still higher significantly than the control treatment. Using high concentration of Pb element caused non-significant increase in root length, whereas they caused a significant decrease in root diameter which reached to 0.29 and 0.32 cm compared to the plants that not received this element (0.38 cm). Interactions between Ni and Pb effects on the vegetative growth differ according to the studied characteristics, where only the interactions of 0 and 30 $mg.kg^{-1}$ Ni with different Pb concentrations increased the plant height and plant leaves number significantly in comparison to the control treatment, whereas, differences between the control treatment and most other interactions were not differed significantly regarding the plants stems diameter. Interactions of 15 and 30 $mg.kg^{-1}$ Ni with different Pb concentrations increased the plant leaf area significantly compared to the control treatment, whereas, the interactions of 45 $mg.kg^{-1}$ Ni cause a significant decrease in this characteristic. Dry matter percentage of each of shoot and root was affected non-significantly by each of Ni and Pb application in compare to the non-treated plants. Regarding root length most interactions of Ni decreased them significantly. Most of the interactions were not differed significantly except the significant increase in root diameter which reached to 0.43 cm for each of N0Pb15, N15Pb0, and Ni15Pb45 treatments respectively. Same results were gained by many researchers, where Pb treatment cause a significant reduction in the germination of seeds, length of shoot, seedling dry weight and many other characteristics when compared to the control treatment (Mehboob, et al., 2018; Ahmad, *et al.*,2009; Muhammad, *et al.*,2008; Seregin and Kozhevnikova, 2006 and Le´on et al., 2005). With regard to the characteristics of the vegetative growth, root nodules is not formed in Gleditsia plant genus (Figure 2), where *Gledistsia* genus is phyllogenetically located at the base of the fabaceae family where there is no nodules among the species of this genus (Faria and Olivares, 2022), however the root form some hypertrophic outgrowth, where there are bacteria found inside structures which are very like to infection threads in legumes, and nitrogenase enzyme is present in this material (Faria, et al. 2002).

3.2. Effects of nickel, lead and their interactions on seed performance, some vegetative growth and nodules of *L. leucocephala*

Results in Table (3) show that each of Ni and Pb had significant effects on the percent and velocity of seed germination, and some growth parameters for *L. leucocephala* seedling. It is clarify that increasing Ni concentration cause a significant decrease in the percent of seed germination, where the highest value (38.4%) was recorded for untreated plants, whereas the low value (22.3%) was recorded for the high concentration (45mg.kg^{-1} soil), this decrease in the percent of seed germination may due to harmful effects on the mineral nutrients content, sugar transport, water balance, distract membranes function and ion balance of cytoplasm particularly K^+ ion (Kumar, et al.,2019). This study appears that the velocity of germination significantly increased with Ni application (Zayed, et al.,2012). Also for Pb application the highest germination percent (34.3%) was recorded in the control treatment, while a lower germination percent was recorded for the 30 mg.kg-1 soil, whereas high concentration of Pb (45 mg.kg-1 soil) decreased the velocity of germination to 21.3 days compared to no Pb treatment. Ni application significantly increased plant high at all concentrations, while increased significantly at Ni15, Ni45 plant leaf area and shoot dry weight at Ni30. Both Ni30, Ni45 increased significantly percentage root dry matter and nodules number as compare to control, whereas it doesn't had a significant effect on the stem and root diameter, plant leaves number and nodules dry matter percent. At the same time Pb had no significant effects on each stem diameter root and nodules dry matter percent. The results from Table (3) indicate the effect of Ni was toward increasing the vegetative growth, compared to the Pb application, and this may due to Ni is consider as essential element for the growth and development of plants, whereas Pb is not, because Ni at low concentrations is one of essential micronutrients for seeds germination and plant growth, whereas, it toxicity appear with its high concentration in the soil and plants, although tolerance efficiency depends on the plant species. Excessive amount of toxic element typically caused decrease in germination of seeds and growth of plants (Table 3), whereas Pb is one of the heavy metals not essential in cell metabolism processes, but it`s absorption is very easy, so they accumulated in different parts of plants. Pb element inhibits seed germination, also delays seedlings growth, it inhibits photosynthesis process, declines in minerals nutrition, growth stunting, and other symptoms, and may lead to a cell death at high level concentrations. All these disorders distressed normal physiological activities of the plant (Fazal, 2015, and Sharma and Dubey, 2005).

Interactions between two elements Ni and Pb on the percent of seed germination most of the interactions were not differ significantly from the control treatment, but the interactions between the highest concentrations levels of Ni and Pb decreased the percent of seed germination significantly (Table 3). Some seedling growths such as plant height, plant leaf area, dry matter of root and nodules number were increased significantly with increasing Ni and Pb concentrations levels, while number of leaves was decreased with increasing the concentrations. These changes in plants exposed to Pb element where described by Fahr, et al.(2013), where the plants already developed many tolerance mechanisms that are triggered as a response to the exposure to Pb element, this element usually affects through plant root systems which respond rapidly through either by callus synthesis and deposition, ending Pb entering by creating a barriers, or uptakes large amount of Pb then restoration in the vacuole which supplemented many changes in root branching and growth, and finally by translocation the Pb to the hyper-accumulators plant shoots.

L. leucocephala was more tolerant to the increase of Ni and Pb concentrations levels. Some species can growth at higher metal concentrations, which are highly toxic to other species. The results showed that Ni and Pb were less toxic metals for *L. leucocephala* plant species. The result shows that the low concentrations of nickel chloride are required for the normal growth of plants. Whereas, increasing in nickel chloride levels will reduced seed germination and subsequent plant growth and as a result cause toxicity (Ahmad, et al.,2009). Same result was described by Shweti, et al. (2018) that Ni at low concentration is consider essential micronutrient for seed germination and the growth for wheat, however, toxicity will appear with high concentration in the soil and plants. However the tolerance efficiency will depends on the species of the plant. Also Pavlova, et al., (2018), who studies the effect of Ni on *Alyssum markgrafii* and *A. mural* seeds, where the ability to germination decreased with increasing the Ni concentrations, whereas hypocotyl elongation were stimulated at low Ni concentrations, but the root elongation was inhibited for both species, which firm that the plant roots were more sensitive than hypocotyl to Ni element.

3.3. Effects of nickel, lead and their interactions on seed performance, some vegetative growth and nodules of *R. pseudoacacia*

The results of Table (4) shows that Ni application to the soil had a significant effects on all the studied characteristics for seeds performance and the growth of seedling of *R. pseudoacacia* except the percent of root dry matter, where the differences were not significant. Increasing concentration of Ni led to a decrease in the percent of seed germination significantly to 16.4% for the highest Ni concentration (45 $mg.kg^{-1}$ soil) compared to no Ni treatment (57.5%), however, this decrease was offset by a significant decrease in days for seed germination with increasing the concentration to reach 24.8 days for the 45 $mg.kg^{-1}$ soil treatment compared to no Ni application plants (40.1 days), because it appears toxicity with high concentrations in the soil and plants. However, tolerance efficiency depends on the plants species, same results were obtained by (Shweti, et al., 2018) who establish that low concentrations of Ni consider as stimulator for wheat seed emerging, whereas, high concentrations are toxic. Regarding the effects of Pb on seed performance, it is shown that there were non-significant differences between Pb concentrations with no Pb application in respect to the percent and velocity of seed germination. For the interaction between Ni and Pb, there were significant effects on the percent and velocity of seed germination, and it is appear that the interaction of low concentrations of each of Ni and Pb (15 $mg.kg^{-1}$) gave the best combination (74.7 % and 26.2 days) for the percent and velocity of seed germination.

Regarding the vegetative growth and nodules, Ni application significantly increased root diameter and nodules dry mater percentage at all treatments as compare to control, while decreased significantly other plant characteristics, it may due to a higher activation of the stores to the rest of the root nodules, prompting an enlarge in the root nodules dry weight (Sahu,et al., 2020). There were non-significant differences between the control with most Pb concentrations especially for the plant height, stem diameter, plant leaves number, percent of shoot dry matter, root diameter, and percent of nodules dry matter, whereas plant leaf area significantly increased at all treatments and the highest value was by adding Pb at concentration Pb15. Inversely Pb application causes a significant decrease in plant root length, because those plants grow under the stress of heavy metals suffering a shortage in the energy amount required for a good growth of the plants grown in stressed environment (Tai, et al.,2022 and Kang, et al., 2018). Regarding the nodules number there were significant differences between all Pb treatments, where the highest value found in the 30 $mg.kg^{-1}$ whereas the lowest value was in 45 $mg.kg^{-1}$ treatment.

Most interactions effect between Ni and Pb concentrations on the vegetative growth and nodules parameters, effects non-significantly compared to the control plants in respect to plant height, plant stem diameter, and plant leaf area, whereas interactions of high concentrations of Ni (30 and 45 $mg.kg^{-1}$) cause a significant decrease in plant leaves number, percent of shoot dry matter, root length, and nodules number, on the other hand these interactions increased the root diameter significantly compared to the control treatment plants. It appears from Table (4) results that high concentrations of nickel affects were more toxic than lead, because of the higher differences between Ni treatments than that of Pb element. These results indicated that little amount of the salt nickel chloride is required for stimulating *R. pseudoacacia* seed performance and seedling growth, whereas, increasing levels of nickel chloride decreased seed germination and the growth of plant and cause toxicity, because of nickel is one of the essential micronutrients for germination of seeds and subsequent plant growth at low concentrations, whereas it is become toxic with high concentrations in the plant and soil. However the efficacy of elements tolerance depends on the species of the plant (Singh, 2020; Anwar, et al., 2022; Kabira, et al., 2018; Sharifi, 2017; Jaime, et al.,2012, and Singh, et al., 2010). Inhibition of root growth is clear in plants treated with Pb which agrees with Fazal, (2015) and Sharma and Dubey (2005).

Differences were seen between the studied plants regarding most of the vegetative growth parameters because heavy metals uptake and accumulation is vary even from species to species within a genus (Kun, et al., 2021), and the contaminants distribution in a plant is minded by the plant physiological character, and the distribution depends on the mobility of the contaminant in the plant tissues, on the type of plant, and the conditions of its growth Štofejová, et al (2021). Low seeds germination for the studied species were clear, which may be due to germination condition especially the high temperature, where the average temperature during the germination period was 10-39 °C (Table 1) that is more than the optimal temperature for most seeds germination. Regarding the results of these specie after seeds soaking for 24 hours, it was seen that the seeds coat of *G. triacanthos*, was more rigid than *R. pseudoacacia* seeds, which is more rigid than *L. leucocephala* seeds, this property is appear from the results of Tables (2, 3 and 4) where it was seen that effect of Ni and Pb on *G. triacanthos* germination performance was less than other species, which may due to the accumulation of the metals in the coat of seeds, while the endosperm appeared to be lacking of Ni and Pb, and the coats of seed can decrease the amount of Ni and Pb entering the seeds (Le´on, *et al.*, 2005). Decreasing in germination velocity is clear where Ni is used for the three species because Ni is consider as one of the essential mineral elements for plants which is required in small amounts for healthy growth and development (Kun, et al., 2021; Joseph, et al.,2018 and Abdel Aziz, et al., 2014). From the figure (2) it is seen that the growth of each of *L. leucocephala* and *R. pseudoacacia* species was more than that of *G. triacanthos* species, and this may due to the exist of root nodules, which the host plants delivers energy as photosynthate and, on the other hand receives nitrogen combination for its growth and development (Yusuf, et al., 2011). As it appears from Figure (2) all the nodules for *L. leucocephala* and *R. pseudoacacia* species were distributed on secondary roots. The rhizobia exist inside nodules fixed the atmospheric N into ammonia which is considered a nitrogen source for the legumes. Increasing nodules number and dry matter and some other parameters for *L. leucocephala* and *R. pseudoacacia* species may due to exist of some rhizobia including that strains resistant to heavy metals and can stimulate the growth of plants under the stress of heavy metal (De Angelis, et al., 2022). Generally, we saw that effects of Pb was less compared to Ni because lead is not an essential element and is considered relatively unavailable for living organisms due to immobilization in soil and the transportation from roots to plants is limited (Kacálková, *et al.,* 2014).

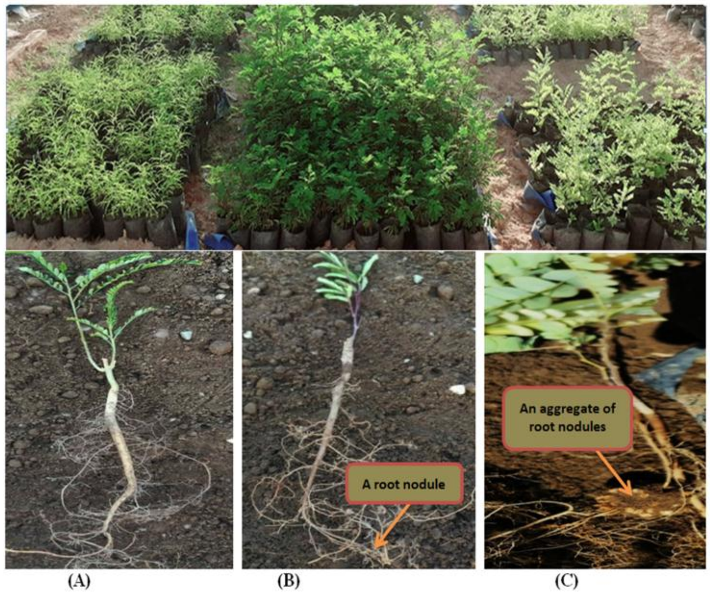

Figure 2. Each column illustrates the seedling growth in field and the seedling with roots, for (A) *G. triacanthos, (B) L. leucocephala* and *(C) R. pseudoacacia* species

CONCLUSIONS AND RECOMMENDATIONS:

The results of this study indicated each of *G. triacanthos*, *L. leucocephala*, and *R. pseudoacacia* species that grown in soils contaminated with Ni and Pb show different responses regarding germination performance, vegetative growth, and nodules. In general, high concentrations especially the 45 $mg.kg^{-1}$ soil in combination with lead had more effects on the studied characteristics. Also, results showed that metal tolerance differs significantly between the species, where *R. pseudoacacia* was the best for germination velocity, and *L. leucocephala* for most vegetative growth parameters followed by *G. triacanthos* then *R. pseudoacacia*. Also we can conclude that Ni was more effective on seed and growth performance than Pb element, whereas Pb is significantly increased leaf area of both *R. pseudoacacia* and *G. triacanthos* for all treatments, while for L. leucocephala increased only at 45mg/g. This study needed to be completed in order to determine maximum amount of Ni and Pb that plants can tolerate, and the ability of these fabaceae species to other heavy metals

Table 2. Effects of nickel, lead and their interactions on some vegetative growth of *G. triacanthos* plant.

Treatments	Germination		Plant Height (cm)	Stem diameter (cm)	Plant Leaves Number	Plant Leaf Area (cm^2)	Shoot Dry Matter (%)	Root Length (Cm)	Root diameter (cm)	Root Dry Matter (%)
	Percent (%)	Velocity Days)								
Nickel con. ($mg.kg^{-1}$ soil)										
Ni 0	55.7^{a}	37.1^{a}	28.9^{ab}	0.28^{ab}	14.8^{a}	17.7^{b}	64.5^{a}	26.0^{a}	0.36^{a}	71.1^{a}
Ni 15	54.0^{a}	35.9^{a}	27.6^{b}	0.25^{b}	12.5^{b}	25.7^{a}	57.0^{a}	20.9^{b}	0.33^{ab}	82.8^{a}
Ni 30	48.2^{a}	33.8^{a}	31.0^{a}	0.31^{a}	15.4^{a}	26.4^{a}	50.8^{a}	24.3^{a}	0.34^{ab}	77.6^{a}
Ni 45	50.1^{a}	29.7^{b}	29.6^{ab}	0.28^{ab}	14.1^{a}	8.3^{c}	54.3^{a}	25.8^{a}	0.30^{b}	77.5^{a}
Lead con. ($mg.kg^{-1}$ soil)										
Pb 0	54.8^{a}	36.2^{a}	29.5^{ab}	0.28^{a}	14.1^{a}	16.9^{c}	55.8^{a}	23.9^{ab}	0.38^{a}	76.1^{a}
Pb 15	55.7^{a}	35.1^{a}	31.4^{a}	0.29^{a}	14.9^{a}	21.9^{a}	60.7^{a}	23.3^{b}	0.34^{ab}	75.9^{a}
Pb 30	48.1^{a}	34.1^{ab}	29.0^{bc}	0.28^{a}	14.1^{a}	19.7^{b}	57.0^{a}	24.4^{ab}	0.29^{c}	77.1^{a}
Pb 45	49.4^{a}	31.2^{b}	27.2^{c}	0.28^{a}	13.6^{a}	19.6^{b}	53.0^{a}	25.4^{a}	0.32^{bc}	79.7^{a}
Interaction between Ni and Pb concentrations										
Ni0 Pb0	53.0^{a}	47.9^{a}	25.1^{def}	0.27^{abc}	11.4^{de}	14.2^{cd}	64.7^{a}	26.0^{abcde}	0.33^{bc}	65.7^{ab}
Ni0 Pb15	38.0^{a}	38.4^{bc}	34.1^{a}	0.33^{a}	15.2^{abc}	22.7^{b}	64.8^{a}	23.0^{defg}	0.43^{a}	66.7^{ab}
Ni0 Pb30	49.0^{a}	36.5^{cd}	24.1^{ef}	0.23^{bc}	16.2^{ab}	16.3^{c}	65.8^{a}	30.0^{a}	0.37^{ab}	78.7^{ab}
Ni0 Pb45	60.3^{a}	25.5^{g}	32.3^{ab}	0.30^{ab}	16.1^{ab}	16.3^{c}	62.9^{a}	25.2^{bcdef}	0.30^{bcd}	73.1^{ab}
Ni15 Pb0	49.7^{a}	36.9^{c}	28.7^{bcde}	0.27^{abc}	14.9^{abcd}	32.0^{a}	43.4^{a}	21.2^{fg}	0.43^{a}	78.8^{ab}
Ni15 Pb15	63.7^{a}	28.1^{defg}	30.0^{abcd}	0.27^{abc}	11.1^{e}	23.0^{b}	64.4^{a}	19.3^{g}	0.27^{cd}	83.0^{ab}
Ni15 Pb30	51.0^{a}	34.9^{cdef}	29.7^{abcd}	0.26^{abc}	12.0^{cde}	25.3^{b}	55.8^{a}	22.0^{efg}	0.17^{e}	76.7^{ab}
Ni15 Pb45	51.7^{a}	35.3^{cde}	22.2^{f}	0.20^{c}	12.1^{cde}	22.5^{b}	39.4^{a}	21.1^{fg}	0.43^{a}	92.6^{a}
Ni30 Pb0	56.0^{a}	28.2^{defg}	34.2^{a}	0.30^{ab}	15.2^{abc}	11.5^{de}	66.3^{a}	21.4^{fg}	0.37^{ab}	85.3^{ab}
Ni30 Pb15	55.0^{a}	46.0^{ab}	31.5^{ab}	0.30^{ab}	14.4^{abcde}	33.0^{a}	54.3^{a}	23.0^{cdef}	0.37^{ab}	80.5^{ab}
Ni30 Pb30	41.7^{a}	38.5^{bc}	32.3^{ab}	0.30^{ab}	15.1^{abc}	31.0^{a}	57.0^{a}	23.1^{cdefg}	0.33^{bc}	82.7^{ab}
Ni30 Pb45	40.0^{a}	31.0^{cdefg}	25.6^{cdef}	0.33^{a}	16.7^{a}	30.3^{a}	50.3^{a}	29.0^{ab}	0.30^{bcd}	61.7^{b}
Ni45 Pb0	60.7^{a}	31.6^{cdefg}	30.0^{abcd}	0.27^{abc}	14.9^{abcd}	10.0^{ef}	48.8^{a}	27.1^{abcd}	0.37^{ab}	74.6^{ab}
Ni45 Pb15	66.0^{a}	27.8^{efg}	30.2^{abc}	0.27^{abc}	13.7^{abcde}	9.0^{ef}	59.3^{a}	27.2^{abc}	0.30^{bcd}	73.4^{ab}
Ni45 Pb30	50.7^{a}	26.5^{fg}	29.8^{abcd}	0.33^{a}	13.0^{bcde}	6.0^{f}	49.6^{a}	22.7^{efg}	0.30^{bcd}	70.5^{ab}
Ni45 Pb45	45.7^{a}	32.9^{cdefg}	28.7^{bcde}	0.27^{abc}	14.7^{abcd}	8.0^{ef}	59.3^{a}	26.1^{abcde}	0.23^{de}	91.4^{a}

Table 3. Effects of nickel, lead and their interactions on some vegetative growth of *L. leucocephala* plant.

Treatments	Germination		Plant Height (cm)	Stem diameter (cm)	Plant Leaves Number	Plant Leaf Area (cm^2)	Shoot Dry Matter (%)	Root Length (cm)	Root diameter (cm)	Root Dry Matter (%)	Nodules Number	Nodules Dry Matter (%)
	Percent (%)	Velocity (Days)										
Nickel con. ($mg.kg^{-1}$ soil)												
Ni 0	38.4^{a}	20.1^{c}	40.0^{b}	0.40^{a}	9.0^{a}	29.6^{b}	53.1^{b}	32.2^{ab}	0.55^{a}	73.0^{b}	5.50^{c}	57.6^{a}
Ni 15	33.3^{ab}	21.1^{c}	45.3^{a}	0.38^{a}	9.3^{a}	34.6^{a}	61.4^{ab}	30.0^{b}	0.50^{a}	81.8^{ab}	5.33^{c}	61.7^{a}
Ni 30	29.8^{b}	42.5^{a}	44.7^{a}	0.38^{a}	9.7^{a}	27.2^{c}	70.8^{a}	32.0^{ab}	0.54^{a}	84.0^{a}	9.25^{a}	60.3^{a}
Ni 45	22.3^{c}	24.5^{b}	44.1^{a}	0.37^{a}	9.3^{a}	35. 4^{a}	65.3^{ab}	34.2^{a}	0.50^{a}	85.4^{a}	8.41^{b}	50.8^{a}
Lead con. ($mg.kg^{-1}$ soil)												
Pb 0	34.3^{a}	26.7^{b}	43.1^{ab}	0.38^{a}	9.5^{a}	30.1^{b}	72.0^{a}	34.7^{a}	0.55^{a}	79.8^{a}	6.33^{c}	56.4^{a}
Pb 15	32.3^{ab}	33.7^{a}	45.5^{a}	0.40^{a}	10.0^{a}	31.7^{b}	68.8^{a}	31.2^{b}	0.54^{ab}	82.2^{a}	8.33^{a}	67.6^{a}
Pb 30	26.8^{b}	26.5^{b}	44.5^{a}	0.39^{a}	9.8^{a}	30.1^{b}	55.6^{b}	31.6^{ab}	0.51^{ab}	83.2^{a}	7.25^{b}	55.3^{a}
Pb 45	30.3^{ab}	21.3^{c}	40.9^{b}	0.36^{a}	8.1^{b}	34.8^{a}	54.1^{b}	30.9^{b}	0.49^{b}	78.9^{a}	6.58^{bc}	51.1^{a}
Interaction between Ni and Pb concentrations												
Ni0 Pb0	37.3^{abc}	18.6^{de}	37.3^{bc}	0.40^{ab}	10.5^{ab}	24.0^{e}	60.4^{a-d}	44.0^{a}	0.53^{bc}	50.0^{c}	3.3^{g}	48.5^{a}
Ni0 Pb15	33.3^{a-d}	27.7^{c}	45.5^{a}	0.47^{a}	9.3^{a-d}	32.4^{bc}	67.7^{abc}	30.5^{bcd}	0.53^{bc}	89.0^{a}	6.7^{def}	77.9^{a}
Ni0 Pb30	38.3^{ab}	19.1^{de}	43.0^{a}	0.37^{ab}	10.4^{ab}	28.5^{cd}	30.5^{e}	30.2^{bcd}	0.67^{a}	87.7^{a}	6.7^{def}	52.1^{a}
Ni0 Pb45	44.7^{a}	15.0^{e}	33.9^{c}	0.37^{ab}	6.3^{e}	33.5^{ab}	53.7^{b-e}	24.1^{d}	0.47^{bc}	65.3^{bc}	5.3^{f}	52.0^{a}
Ni15 Pb0	32.3^{a-e}	24.8^{cd}	45.0^{a}	0.37^{ab}	8.5^{cd}	36.3^{ab}	75.6^{abc}	30.9^{bcd}	0.57^{ab}	90.1^{a}	6.3^{ef}	54.7^{a}
Ni15 Pb15	29.0^{b-f}	20.9^{de}	45.4^{a}	0.37^{ab}	9.8^{a-d}	32.5^{bc}	85.8^{a}	28.1^{bcd}	0.53^{bc}	76.5^{ab}	7.3^{cde}	73.1^{a}
Ni15 Pb30	27.0^{b-g}	19.3^{de}	45.5^{a}	0.43^{ab}	10.2^{abc}	32.7^{bc}	50.2^{cde}	25.9^{cd}	0.43^{c}	73.7^{ab}	5.0^{f}	66.3^{a}
Ni15 Pb45	44.7^{a}	19.7^{de}	45.0^{a}	0.37^{ab}	8.9^{bcd}	36.9^{ab}	34.0^{de}	35.9^{b}	0.47^{bc}	86.7^{a}	2.7^{g}	52.9^{a}
Ni30 Pb0	44.7^{a}	43.0^{b}	46.5^{a}	0.37^{ab}	9.8^{a-d}	25.9^{de}	82.7^{ab}	28.9^{bcd}	0.53^{bc}	90.1^{a}	9.0^{abc}	74.0^{a}
Ni30 Pb15	44.7^{a}	58.3^{a}	44.9^{a}	0.37^{ab}	11.0^{a}	24.6^{de}	58.4^{a-e}	32.2^{bc}	0.57^{ab}	81.5^{ab}	10.7^{a}	62.7^{a}
Ni30 Pb30	16.3^{fg}	39.7^{b}	44.8^{a}	0.40^{ab}	9.3^{a-d}	23.1^{e}	79.6^{abc}	35.2^{b}	0.50^{bc}	82.1^{ab}	8.3^{bcd}	63.8^{a}
Ni30 Pb45	13.7^{g}	29.1^{c}	42.4^{ab}	0.37^{ab}	8.8^{bcd}	35.0^{ab}	62.5^{a-d}	31.4^{bc}	0.57^{ab}	82.0^{ab}	9.0^{abc}	40.8^{a}
Ni45 Pb0	23.0^{c-g}	20.6^{de}	43.3^{a}	0.37^{ab}	9.5^{a-d}	34.1^{ab}	69.0^{abc}	34.9^{b}	0.57^{ab}	89.0^{a}	6.7^{def}	48.5^{a}
Ni45 Pb15	22.3^{d-g}	30.0^{c}	46.1^{a}	0.40^{ab}	10.1^{a-d}	37.5^{a}	63.4^{a-d}	34.1^{b}	0.53^{bc}	81.6^{ab}	8.7^{bc}	56.7^{a}
Ni45 Pb30	25.7^{b-g}	28.0^{c}	44.8^{a}	0.37^{ab}	9.3^{a-d}	36.1^{ab}	62.2^{a-d}	34.9^{b}	0.43^{c}	89.2^{a}	9.0^{abc}	39.0^{a}
Ni45 Pb45	18.3^{efg}	20.6^{de}	42.2^{ab}	0.33^{b}	8.2^{d}	33.7^{ab}	66.4^{abc}	32.8^{bc}	0.47^{bc}	81.6^{ab}	9.33^{ab}	59.0^{a}

* Means followed by the same letters with in columns are not significantly different at $p \leq 0.05$ according to the Duncan test.

Table 4. Effects of nickel, lead and their interactions on some vegetative growth of *R. pseudoacacia* plant.

Treatments	Germination		Plant Height (cm)	Stem diameter (cm)	Plant Leaves Number	Plant Leaf Area (cm^2)	Shoot Dry Matter (%)	Root Length (Cm)	Root diameter (cm)	Root Dry Matter (%)	Nodules Number	Nodules Dry Matter (%)
	Percent (%)	Velocity (Days)										
Nickel con. (mg.kg^{-1} soil)												
Ni 0	57.5 ^{a}	40.1 ^{a}	28.33 ^{a}	0.40 ^{a}	16.65 ^{a}	31.71 ^{a}	67.98 ^{a}	34.20 ^{a}	0.26 ^{c}	69.46 ^{a}	10.67 ^{a}	49.43 ^{b}
Ni 15	55.8 ^{a}	28.8 ^{b}	25.55 ^{b}	0.36 ^{a}	12.88 ^{b}	28.46 ^{b}	48.66 ^{b}	30.20 ^{b}	0.33 ^{b}	66.46 ^{a}	9.42 ^{b}	64.37 ^{a}
Ni 30	53.7 ^{a}	25.2 ^{c}	23.30 ^{c}	0.32 ^{b}	8.63 ^{c}	28.33 ^{b}	63.43 ^{ab}	28.83 ^{b}	0.34 ^{b}	71.60 ^{a}	8.25 ^{c}	64.30 ^{a}
Ni 45	16.4 ^{b}	24.8 ^{c}	24.11 ^{bc}	0.30 ^{b}	8.40 ^{c}	25.21 ^{c}	48.26 ^{b}	25.1 ^{c}	0.40 ^{a}	70.38 ^{a}	4.67 ^{d}	62.20 ^{a}
Lead con. (mg.kg-1 soil)												
Pb 0	47.67 ^{ab}	29.5 ^{ab}	26.41 ^{a}	0.35 ^{a}	11.46 ^{b}	24.54 ^{d}	63.1 ^{a}	31.67 ^{a}	0.34 ^{ab}	70.23 ^{a}	9.33 ^{b}	58.99 ^{ab}
Pb 15	54.42 ^{a}	31.0 ^{a}	22.78 ^{b}	0.31 ^{b}	11.61 ^{ab}	32.50 ^{a}	62.83 ^{a}	28.38 ^{b}	0.31 ^{b}	73.61 ^{a}	6.67 ^{c}	53.35 ^{b}
Pb 30	38.1 ^{b}	28.3 ^{b}	25.51 ^{a}	0.34 ^{ab}	13.50 ^{a}	29.54 ^{b}	56.48 ^{ab}	29..33 ^{b}	0.35 ^{a}	68.23 ^{a}	11.75 ^{a}	67.45 ^{a}
Pb 45	43.3 ^{ab}	30.0 ^{ab}	26.58 ^{a}	0.36 ^{a}	10.00 ^{b}	27.13 ^{c}	45.96 ^{b}	28.90 ^{b}	0.32 ^{ab}	65.83 ^{a}	5.25 ^{d}	60.50 ^{ab}
Interaction between Ni and Pb concentrations												
Ni0 Pb0	15.3 ^{b}	38.9 ^{bc}	27.53 ^{b}	0.37 ^{bc}	16.23 ^{a}	28.00 $^{d-g}$	71.67 ^{ab}	34.67 ^{ab}	0.23 ^{e}	69.63 ^{a}	13.33 ^{a}	44.07 ^{d}
Ni0 Pb15	17.7 ^{b}	45.1 ^{a}	25.57 ^{bc}	0.37 ^{bc}	15.23 ^{a}	36.00 ^{a}	65.93 $^{a-d}$	37.53 ^{a}	0.23 ^{e}	69.27 ^{a}	10.00 ^{cd}	49.10 ^{cd}
Ni0 Pb30	21.7 ^{b}	35.7 ^{cd}	26.97 ^{b}	0.37 ^{bc}	18.47 ^{a}	32.33 ^{bc}	72.67 ^{ab}	31. ^{bcd}	0.30 ^{cde}	65.80 ^{a}	12.33 ^{ab}	52.07 ^{bcd}
Ni0 Pb45	11.0 ^{b}	40.5 ^{b}	33.77 ^{a}	0.47 ^{a}	16.67 ^{a}	30.50 $^{b-e}$	61.67 $^{a-d}$	33.10 ^{bc}	0.27 ^{de}	73.13 ^{a}	6.67 ^{ef}	52.47 ^{bcd}
Ni15 Pb0	56.0 ^{a}	32.3 ^{ef}	25.57 ^{bc}	0.43 ^{ab}	11.13 ^{b}	25.33 ^{fg}	42.23 ^{bcd}	32.13 ^{bcd}	0.30 ^{cde}	68.90 ^{a}	10.00 ^{cd}	72.33 ^{ab}
Ni15 Pb15	74.7 ^{a}	26.2 ^{fgh}	25.00 ^{bcd}	0.30 ^{cd}	16.00 ^{a}	32.83 ^{ab}	60.67 $^{a-d}$	30.97 ^{bcd}	0.37 ^{bc}	81.03 ^{a}	7.00 ^{ef}	58.17 ^{bcd}
Ni15 Pb30	25.7 ^{b}	29.1 ^{ef}	25.87 ^{bc}	0.33 ^{cd}	16.87 ^{a}	27.67 ^{efg}	52.97 $^{a-d}$	29.10 ^{de}	0.37 ^{bc}	57.00 ^{a}	14.00 ^{a}	69.63 ^{abc}
Ni15 Pb45	72.3 ^{a}	27.6 ^{fgh}	25.57 ^{bc}	0.37 ^{bc}	7.53 ^{b}	28.00 $^{d-g}$	35.77 ^{d}	28.57 ^{de}	0.30 ^{cde}	58.90 ^{a}	6.00 ^{ef}	57.33 ^{bcd}
Ni30 Pb0	58.3 ^{a}	21.5 ^{i}	25.53 ^{bc}	0.30 ^{cd}	8.90 ^{b}	28.83 $^{c-f}$	65.07 ^{ac}	30.0 ^{cde}	0.37 ^{bc}	65.13 ^{a}	8.00 ^{de}	63.00 ^{bcd}
Ni30 Pb15	65.3 ^{a}	28.7 ^{efg}	21.90 ^{cde}	0.30 ^{cd}	7.77 ^{b}	29.67 $^{b-e}$	82.60 ^{a}	23.67 ^{fg}	0.30 ^{cde}	67.60 ^{a}	6.33 ^{ef}	45.00 ^{d}
Ni30 Pb30	53.7 ^{a}	24.7 ^{ghi}	21.10 ^{de}	0.37 ^{bc}	9.43 ^{b}	29.50 $^{b-e}$	64.27 $^{a-d}$	30.30 ^{cde}	0.40 ^{ab}	91.83 ^{a}	13.67 ^{a}	86.13 ^{a}
Ni30 Pb45	52.7 ^{a}	25.8 ^{fgh}	24.67 ^{bcd}	0.30 ^{cd}	8.43 ^{b}	25.33 ^{fg}	41.77 ^{bcd}	31.33 ^{bcd}	0.30 ^{cde}	63.80 ^{a}	5.00 ^{fg}	63.07 ^{bcd}
Ni45 Pb0	61.0 ^{a}	25.5 ^{fgh}	27.53 ^{b}	0.30 ^{cd}	9.57 ^{b}	16.00 ^{h}	70.23 ^{abc}	29.87 ^{cde}	0.47 ^{a}	77.27 ^{a}	5.33 ^{fg}	56.57 ^{bcd}
Ni45 Pb15	60.0 ^{a}	23.9 ^{hi}	18.67 ^{e}	0.27 ^{d}	7.43 ^{b}	31.50 ^{bcd}	42.10 ^{bcd}	21.33 ^{g}	0.33 ^{bcd}	78.53 ^{a}	3.33 ^{g}	61.13 ^{bcd}
Ni45 Pb30	51.3 ^{a}	23.7 ^{hi}	28.10 ^{b}	0.30 ^{cd}	9.23 ^{b}	28.67 $^{c-f}$	36.03 ^{cd}	26.47 ^{ef}	0.33 ^{bcd}	58.27 ^{a}	6.67 ^{ef}	61.97 ^{bcd}
Ni45 Pb45	51.0 ^{a}	25.8 ^{fgh}	22.13 ^{cde}	0.30 ^{cd}	7.33 ^{b}	24.67 ^{g}	44.63 ^{bcd}	22.57 ^{fg}	0.40 ^{ab}	67.47 ^{a}	3.33 ^{g}	69.13 ^{abc}

* Means followed by the same letters with in columns are not significantly different at $p \leq 0.05$ accordin to the Duncan test

References:

Abdel Aziz, H. A and Galal, Y.G.M. (2014). Influence of different levels of phosphorus and potassium on growth of *Leucaena leucocephala* seedlings. J. Soil Sci. and Agric. Eng., Mansoura Univ., 5 (2): 135-143.

Abdul, K. S. (2009). Rooting stimulation of four apple (*Malus domestica*) cutting cultivars by using plant growth regulators. Ph.D. thesis, Salahaddin University, 31-32.

Ahmad, M. S. A; Mumtaz H; Muhammad A; Rashid A and Mhuhammad,Y. A. (2009). Effect of nickel on seed germination of some Elite sunflower (*Helianthus annuus* L.) cultivars. Pak. J. Bot., 41(4): 1871-1882.

Ahmadloo, F; Tabari, M; Yousefzadeh, H; Kooch, Y and Rahmani, A. (2012). Effects of soil nutrient on seedling performance of *Arizona cypress* and medite cypress. Annals of Biological Research 3(3): 1369-1380.

Al-Mohammadi, S.H. and Al-Mohammadi, F., (2002). Statistics and Experimental Design. Dar Osama for Publishing and Distribution, Amman, Jordan. pp.375.

Al-Sahaf, F. H.(1989). Applied Plant Nutrition. Ministry of Higher Education and Scientific Research, University of Baghdad. Al-Hikma House. Iraq. (In Arabic).

Álvarez, S. P Cabezas-Montero, D; Debora-Duarte, B. N Tapia, M. A. M; Sida-Arreola, J.P; Sánchez, E and Héctor-Ardisana, E. F. (2019). Used response to antioxidative enzymes in rice under stress due to lead and nickel, Rev. Mex. Cienc. Agríc:10.

Amjad, M; Raza, H; Murtaza B; Abbas Gh; Imran M; Shahid M; Asif Naeem M; Zakir A and Iqbal M M.(2020). Article Nickel Toxicity Induced Changes in Nutrient Dynamics and Antioxidant Profiling in Two Maize (*Zea mays L*.) Hybrids. Journal plants, 9, 5, www.mdpi.com.

Anwar, KH; Aqsa, N; Yamin, B; Farwa, I; Noshin, I; Ghulam, Y and Muhammad, K. (2022). Lead harms seed germination and growth of *Albizia lebbeck L*. benth and *Prosopis juliflora* (sw.), DC. Pak. J. Bot., 54(1): 121-124.

De Angelis, A; Gasco, L; Parisi, G; Danieli, P.P. A. (2022). Multipurpose leguminous plant for the mediterranean countries: *Leucaena leucocephala* as an alternative protein source: A review animals. PeerJ, 11, 2230.

Deswal, M and Laura, J.S. (2018). Effect of heavy metals cadmium, nickel and lead on the seed germination and early seedling growth of *Pisum sativum*. RJLBPCS 4(2): 3.

Fahr, M; Laurent, L; Najib, B; Valerie, Ho; Mohamed, El; Didier, B and Abdel aziz, S. (2013). Effect of lead on root growth. Frontiers in Plant Science Functional Plant Ecology: 4(6), 175.

Faria, S. M. and Olivares, F. L.(2022). Nodule-structure in the roots of *Gleditsia Spp*. a non-nodulating legume genus. https://www.researchgate.net/publication.

Faria, S.M.; Olivares, F.L and Xavier, R.P. (2002). Nodule-Structure in the Roots of *Gleditsia Spp*. a Non-Nodulating Legume Genus. A chapter in book: Nitrogen Fixation: From Molecules to Crop Productivity: 337-337.

Fazal, H.(2015). A mini review on lead (Pb) toxicity in plants. Journal of Biology and Life Science: 6(2). www.macrothink.org.

Hamad, S.O. and Anwer, L.S. 2021. Effect of re-treatments and sowing depths on germination and early growth of *Leucaena leucocephala* seeds. Zanco Journal of Medical Sciences 33(s1):53-61.

Jaime A; Teixeira da, S; Naeem, M; Idrees, M. (2012). Beneficial and toxic effects of nickel in relation to medicinal and aromatic plants. Medicinal and Aromatic Plant Science and Biotechnology. Global Science Books: 6 (1): 94-104.

Joseph, J; Reddy, J and Sayantan, D.(2018). Effect of nickel uptake on selected growth parameters of *Amaranthus viridis* L. J. Appli. and Natur. Scie. 10 (3): 1011 – 1017.

Kabira, M; Iqbal, M. Z.; Shafiq, M.; Farooqid, Z. R..(2018). The effects of lead and cadmium individually and in combinations on germination and seedling growth of *Leucaena leucocephala* (Lam.) de Wit. Ameri. Scienti. Res. J. Eng. Techn. and Scie. (ASRJETS), http://asrjetsjournal.org.

Kacálková, L; Pavel, T and Jiřina, S. (2014). Chromium, nickel, cadmium, and lead Accumulation in Maize, Sunflower, Willow and Poplar. Pol. J. Environ. Stud. 23 (3): 753-761.

Kang, X, Yu X; Zhang, Y; Cui, Y; Tu, W; Wang, Q; Li, Y; Hu, L; Gu, Y; Zhao, K; Xiang, Q; Chen, Q; Ma, M; Zou, L; Zhang, X and Kang, J.(2018). Inoculation of sinorhizobium saheli YH1 leads to reduced metal uptake for *Leucaena leucocephala* grown in mine tailings and metal-polluted soils. Front. Microbiol. 9:1853. www.frontiersin.org.

Kumar, V; Singh, J and Kumar, P.(2019). Heavy metals accumulation in crop plants: Sources, response mechanisms, stress tolerance and their effects. Agro Environ Media. Haridwar, India.

Kumari, S. and Amarnath, M. (2021). Heavy Metal Contamination. Life sciences. https://www.intechopen.com.

Kun, Li; Han, Xu; Ruiqiang, Ni; Shi, G; Sergiode, M; Chuanrong, Li; Weixing, Sh; Yikun, Zh and Xing, Zh. (2021). Impact of *Robinia pseudoacacia* stand conversion on soil properties and bacterial community composition in Mount Tai, China. hin a Full list of author information is available at the end of the article Lietal. Fores. Ecosys.; 8:19

Le´on, V; Jacques, R; Roger, N; Roxane, B; Xavier, M; Saliou Bouraima-Madje, BI; Josette, V and Rene, P.(2005). Effects of three nickel salts on germinating seeds of grevillea exulvar. rubiginosa, an endemic serpentine Proteaceae. Annal. Bot. 95: 609–618, www.aob.oupjournals.org

Martin, Th. N; José, A. M; Gilberto, L.C; Vinicius, C. S. (2013).Using the imagej software to estimate leaf area in bean crop. Modificado; 38(12). https://www.researchgate.net/publication.

Mehboob, S; Iqbal, M. Z; Shafiq, M.; Kabir, M. and Farooq,.Z. R. (2018). Effects of lead on seed germination and seedling of Wheat (*Triticum as* *sativum L).* GSJ: 6(8):,590. www.globalscientificjournal.com.

Muhammad, Sh; Iqbal, M. Z; Mohammad, A. (2008) . Effect of lead and cadmium on germination and seedling growth of *Leucaena leucocephala.* J. Appl. Sci. Environ. Manage. 12(2) 61 – 66.

Nyiramigisha, P., 2021. Harmful impacts of heavy metal contamination in the soil and crops grown around dumpsites. Reviews in Agricultural Science, 9, pp.271-282.

Pavlova, D; Donaltina, V; Kalina, V; Aida, B; Besmira, Xh. (2018). Effect of nickel on seed germination of Alyssum species with potential for phytomiming in *Albania Fresenius* Environmental Bullet in. https://www.researchgate.net.

Ranal, M. A. and Santana, D. G. d. (2006). "How and why to measure the germination process?" Brazil. J. Bot. 29(1): 1-11.

Sahu, Sh. S; Mohanty, P and Mahalik, G.(2020). Effects of heavy metals on growth and nodulation of Rhizobium sp.in *Vigna radiate (L)* wilczek. Intern. J. Mod. Agri. 9(4): 2305 – 7246.

Seregin, I. V. and Kozhevnikova, A. D.(2006). Physiological role of nickel and its toxic effects on higher plants. Russ. J. Plant Physio. 53(2): 257–277.

Sharifi, M. (2017). Phytotoxic effects of heavy metals on seed germination and seedling growth of medical plant, Hyssop (*Hyssopus officinalis L.*) in Laboratory conditions. J. Medici. Plants and By-prod. 2: 247-253

Sharma, P. and Dubey R.S. (2005). Lead toxicity in plants. Brazil. J. Plant Physio. 17(1), 35-52.

Shweti, A. K and Verma, JS.(2018). Effects of nickel chloride on germination and seedling growth of different wheat (*Triticum aestivum L. em Thell*.) cultivars. J. Pharmaco. and Phytoch. 7(4): 2227-2234.

Singh, A. L; Ram, S. J; Vidya, Ch; Himanshu, B; Seema, J. Sh. (2010).Toxicities and tolerance of mineral elements boron, cobalt, molybdenum and nickel in crop plants. Plant stress. 4 (2), 31-56. https://www.researchgate.net.

Singh, P. (2020). The effect of nickel on seed germination and seedling growth of *Raphanus sativus cv. Jaunpuri*. JETIR: 7(8). www.jetir.org.

Štofejová, L.; Fazekaš, J. and Fazekašová, D. (2021) Analysis of heavy metal content in soil and plants in the dumping ground of magnesite mining factory *Jelšava-Lubeník (Slovakia).* Sustainability: 13: 4508.

Tai, Ch. K. Li; Ruiqiang, Ni; Chaofan, Lv; Lingyu, X; Caihong, Zh; Chuanrong, Li; Weixing, Sh; Huiling, G and Yikun Zh. (2022). The effect of *Robinia pseudoacacia* expansion on the soil particle size distribution on Mount.

Yusuf, M; Fariduddin, Q.; Hayat S. and Ahmad A. (2011). Nickel: An overview of uptake, essentiality and toxicity in plants. Bull. Environ. Contam. Toxicol. 86:1–17.

Zayed, M.Z; Ho, W.S; Fasihuddin, B. A. and Pang, S.L. (2012). Effects of length of soaking in 100 C^{o} water and ems on germination of *Neolamarckia cadamba* and *Leucaena leucocephala* seeds. 4th Regional conference on natural resources in the tropics, (NTrop4).