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Effects of Heavy metals on seed germination and growth of pea, Mustard and Mung bean plants

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Abstract

Additional is the main source of soil pollution come from mining, chemistry, metalworking industries, and other Allies industries. These wastes include varieties of chemicals such as heavy metals, phenol, organic, non-metals, etc. Heavy metals are the intrinsic component of the environment with both essential and not essential both. Soil soiled with heavy metals are customary due to increasing geological and anthropogenic activities. It is the unplanned disposal of municipal waste, mining, use of extensive pesticides, insecticides, fungicides, and other agrochemical applications that were significant causes of pollution and causes of most concern.

Heavy metals such as cadmium, copper, lead, chromium, manganese, iron, and mercury are important environmental pollutants, especially in high anthropogenic pressure areas. Heavy metals collection in the soil relates to agricultural production due to the adverse effect on food safety, marketability, and harvest growth due to phytotoxicity and environmental health of floor organisms. As a result, we may receive confirmation of the fact that the systems we use are sensitive, resilient or both correspond to the respective heavy metals we have selected.

Heavy metal is toxic when the relative concentration of heavy metal as compared to naturally occurring as major is noted for its potential toxicity, especially in environmental contexts. Heavy metal toxicity means excessive concentration than a requirement or it is unwanted which were found naturally on the earth, and become concentrated as a result of human-caused activities, enter in the plant, human tissues via inhalation and manual handling, and can bind to, and interfere with the functioning of vital cellular components[2].

Heavy metals were significant environmental pollutants; their toxicity is a problem of increasing significance for ecological, evolutionary, nutritional, and environmental reasons. They are a group of metals and metalloids with an atomic density greater than 4 g/cm3, or 5 times or more, greater than water including copper (Cu), manganese (Mn), lead (Pb), cadmium (Cd), nickel (Ni), cobalt (Co), zinc (Zn), chromium (Cr), iron (Fe), arsenic (As), silver (Ag) and the platinum. Environmentally it is defined as total circumstances surrounding an organism or group of organisms especially, the combination of external physical conditions that affect and influence the growth, development, and survival of the organisms[1].

They are largely found in dispersed form in rock formations. Increasing industrialization and urbanization had the anthropogenic contribution of heavy metals in the biosphere and had the largest availability in soil and aquatic ecosystems and to a relatively smaller proportion in the atmosphere as particulate or vapors. Its toxicity in plants varies with plant species, specific metal-concentration, chemical form, and soil composition, and pH, as many heavy metals are considered to be essential for plant growth[9].

Some of these heavy metals like Cu and Zn either serve as cofactors or activators of enzyme reactions. It exhibits metallic properties such as ductility, malleability, conductivity, action stability and ligand specificity were characterized by relatively high density and high relative atomic weight with an atomic number greater than 20. Heavy metals such as Co, Cu, Fe, Mn, Mo, Ni, V, and Zn are required in minute quantities by organisms, excessive amounts of these elements can become harmful to organisms[6].

Heavy metals such as Pb, Cd, Hg, and as (a metalloid but generally referred to as heavy metal) do not have any beneficial effect on organisms and are thus regarded as the "main threats" since they are very harmful to both plants and animals, Pollutant in the environment air, water and soil, may be poisonous or toxic and will cause harm to living things. Metals accumulate in the ecological food chain through uptake at the primary producer level and then through consumption at consumer levels and plants roots are the primary contact site for heavy metal ions[7,11,13].

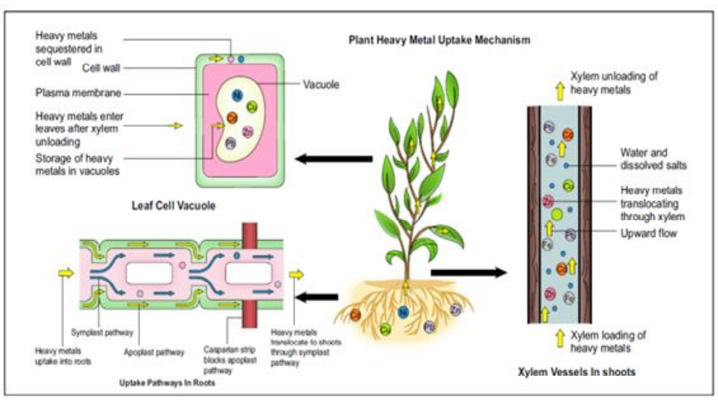

Fig.1: The three processes involved in the absorption and storage of heavy metals.

Whereas, in aquatic systems, the plant body is exposed to these ions and heavy metals are absorbed directly to the leaves due to particles deposited on the foliar surfaces. The soil is one of the most important environmental factors, and the plants depend upon their nutrition, water, and mineral prices. Hybrid products with organisms and degradation. The main inorganic component of the soil is Al, Si, Ca, Mg, Fe, and K. However, its components include B, Mn, Zn, Cu, the main organic ingredients that become the rotation of soils. Along with Carbon, Hydrogen, and Oxygen, the soil is mainly delivered to the nutrients of the main plant. They usually make up more than 90% of the quality of carbon dioxide or water in the atmosphere. The main basic elements and their essential forms and their important forms, N, P, Cu, Mn, Zn, Mb, B, Co, and He[12].

The difference in Some Regional Trees and Plant Species is believed to Provide soil characterizes. The soil supports special plants and animals. The accumulation of heavy metals in the agricultural soil is to increase theme it includes two food safer and health problems and deductions in soil ecosystems. The city administration, domestic or industrial wastes, household or industrial wastes absorb heavy metals in soil. The absorbent metals offer vegetable roots, stems, fruits, cereals, and leaves Fatoki[8]. Soil salt causes access and reduces crop productivity. In addition, the procedure used in this study can be applied to several qualities with the research area of this study.

As the solubility increases, heavy metals are absorbed It is transmitted from there to the root of the shoot via the apoplastic and simplistic path. Of the buds, heavy metals are loaded and transported to the leaves through the xylem. In the leaves, heavy metals are stored in vacuoles[10].

Agriculture plant selection :

For the current research and investigation, three agriculture crop plant species are selected *i.e.*, Pea, Mustard, and Mung bean plants have been selected. The selected parameters were assessed via the regular procedures as specified by APHA[3].

I] Pea plant :

Green peas are common choices for science projects. They germinate dependably in 7 to 10 days and are easy to handle. The beans themselves also resemble peas that children recognize from their food, helping them learn what seeds are and how plants create them.

Peas (Fig. 2,3,4,5) also produce a good-sized, sturdy shoot that's easy to use for projects that require observation of the plant's later growth. Peas seeds are also dependable growers and look like a vegetable those children know. A little harder to handle than peas, they're still a good option and germinate in 7 to 10 days

II] Mung beans :

We use mung beans for our project because its germination time is short that is 4 to 5 days. The mung beans themselves also resemble beans that children recognize from their food, helping them learn what seeds are and how plants create them. Mung beans also produce a good-sized, sturdy shoot that's easy to use for projects that require observation of the plant's later growth.

Fig. 2. Pea plant showing during the trial

Fig. 3. Pea plant during the trial

Fig. 4. Pea plant showing during the trial

Fig. 5. Pea plant showing during the trial

III] Mustard :

We have selected the Mustard plant (Fig. 6,7) for our project because of its characteristics that help us in a great way, such as it takes less time for germination, it is fast-growing and nutritious green leaves.

Fig. 6. Mustard plant Photograph

Fig. 7. Mustard plant selected for study

I] Pea plant :

Temperature: Peas will sprout in 21 to 30 days if the soil temperature is 38 degrees Fahrenheit and the germination rate, or the number of seeds that do sprout, will be below. At temperatures of 65 to 70 F, the seeds will sprout within 7 to 14 days and the germination percentage will be in the high 90s for fresh seeds. Above 75 F the germination percentage goes down quickly even though the seeds sprout quickly. Remember, these are soil temperatures, not air temperatures.

Moisture: Peas are large, hard seeds. Before they can sprout, they must absorb enough water that the endosperm, the food source for the tiny plant, expands to break the seed coat and becomes soft. The seed should be planted an inch deep where the soil does not dry out so quickly and the soil kept moist but not waterlogged. Too much water will cause the seed to rot but too little will delay germination.

Age of Seed: Seed that is saved for several years will have both a lower germination rate and longer germination time. Peas can generally be kept for 3 to 4 years but after that, the seed dries out and the embryos start dying. The extra dry older seed will take longer to absorb enough water to start the germination process even when the embryo is still alive.

Pre-Sprouting: Because peas grow best when the daytime air temperature is 60 to 80 F the soil is often too cold for the seeds to sprout quickly at planting time. By pre-germinating the seeds indoors, you will get a crop sooner. Soak the seeds overnight then lay them out on several damp paper towels. Fold the towels over the seed and place them in a plastic bag. Put the plastic bag in a warm place and keep the towels damp until the seeds sprout. Handle the sprouted seed carefully as you plant.

II] Mung beans :

We use mung beans for our project because its germination time is short that is 4 to 5 days. The mung beans themselves also resemble beans that children recognize from their food, helping them learn what seeds are and how plants create them. Mung beans also produce a good-sized, sturdy shoot that's easy to use for projects that require observation of the plant's later growth.

Sunlight and Temperature: Mung beans are warm-season, deep-rooted plants whose specific hardiness and day-length requirements vary by cultivar, though most require 90 to 120 frost-free days annually. If the mung bean is planted so it blooms during the hottest, driest part of the year, yield may be disappointing. Mung bean plants require full sunlight or at least eight to 10 hours of sunlight daily.

Soil and Fertilization: Mung bean performs best in fertile, well-drained sandy loam soil with a pH between 6.2 and 7.2 and will suffer in poorly-drained, heavy soils. Plants in alkaline soils will display symptoms of nutrient deficiencies. Nitrogen fertilizer is unnecessary, though it may encourage early growth and faster establishment. Mung bean has the same nutrient requirements as other legumes. A soil test is the best way to determine phosphorus and potassium requirements. In fields or gardens where mung beans are planted for the first time, a nitrogen-fixing *Rhizobium* bacteria specifically for mung beans should be applied to the seeds or planting area.

Planting and Spacing: Mung bean planting should occur early enough that harvest will occur before the rainy season and bloom or pod fill will occur before the hottest, driest part of summer and late enough that all danger of frost has passed and soil temperatures are above about 60 degrees Fahrenheit. Two plantings annually, one in spring and another in fall, are often possible in warmer regions. Tilling or cultivating the top several inches of soil break up the ground and controls weeds. Mung bean seeds germinate best when planted 1 to 2 inches deep in moist soil. One seed every 3 inches in rows 18 to 24 inches apart provides an adequate yield.

Irrigation: The deep-rooted mung beans are adapted to warm, dry climates and grow best with only three to five deep watering during the growing season. If the soil is adequately moist at the time of planting, the first watering is not needed until about 20 days after planting. Irrigation timing and frequency needs vary depending on humidity, rainfall, and winds. A regimen with only a few, deep watering limits vegetative growth and encourages seed production. The mung bean requires adequate water between blooming and pod fill.

Sprout Production: Mung bean seeds cultivated for sprouts benefit from different treatment than seeds planted in the ground as a garden plant or field crop. Seeds for sprouts are washed and then soaked in water at 90 degrees Fahrenheit for two to four hours or in water at room temperature overnight before being rinsed and placed in a sprouting container. A porous cushioning pad placed on top of the seeds with a lightweight on it encourages thick yet tender sprouts.

A sprouting temperature between 70- and 80-degrees Fahrenheit ensures the best quality sprouts within four to five days. When temperatures are between 80- and 85-degrees Fahrenheit, sprouts grow slightly faster but are thinner. Sprinkling water over the sprouts every four to six hours for the first four days, then increasing intervals between watering to eight hours is ideal.

III] Mustard (Fig.6,7) *:*

Climate requirements for mustard: Mustard is grown in a subtropical climate. Mustard thrives well in dry and cool climates; therefore, mustard is mostly grown as a rabi season crop. Mustard crops require temperatures between 10°C to 25°C. Mustard crops are grown in areas receiving 625-1000 mm yearly rainfall. This crop does not tolerate frost, so it requires a clear sky with frost-free conditions.

Soil requirement: Mustard can be grown in wide varieties range that ranges from light to heavy loamy soils. Medium to deep soils with good drainage is best suitable for mustard cultivation. Soil's ideal P^H range for mustard is 6.0 to 7.5. Make sure to carry out soil tests to find out these soil properties like soil type, strength, and nutritious levels.

Preparation of Land: One to two ploughings and two harrowing's should be given as part of field preparation. For second crop cultivation, the field should be prepared by giving two crosswise harrowing after the Kharif crop.

The Experimental Design: A pot experiment was conducted using heavy metals. The experiment was designed to identify the differences in the germination and growth of different plants under eight heavy metal stresses. The measurements determined were (a) germination, (b) plant height, and several leaves, in leaves. The eight metals used are copper, cobalt, lead, ferrous, mercury, silver nitrate, zinc, and manganese with five different concentrations of each.

Five different concentrations were used and mixed thoroughly with the soil of a definite amount (1kg) that were passed through a 2 mm sieve (oven-dried base). The five concentrations prepared were 100 mg/kg, 200 mg/kg, 300 mg/kg, and 400 mg/kg, and 500 mg/kg of soil for Cu, Zn, Pb, Fe, Hg, Ag, Co, and Mn. One control was also prepared without applying any heavy metal to compare the effects for each plant. For all the concentrations of Cu, Zn, Pb, Fe, Hg, Ag, Co, Mn, and for control, 5 replicates each was taken making a total of 130 pots.

The soils treated with different concentrations of heavy metals were filled at a definite amount in plastic pots. Seeds of each plant were soaked in cold water for about 6 hours, and then two viable seeds were sown in each pot containing different concentrations of the eight heavy metal treated soils. Each pot was supplied with 150 ml of tap water every alternate day to moisten the soil. The experiment was conducted in a college lab wherein on average the temperature, relative humidity, and light intensity as per the plant requirement.

The observation regarding the germination of the seed was done from the first day of sowing of seeds. Growth and Development of the Plants Growth and development were recorded in terms of plant height and number of leaflets. After one week of germination, the readings/observations were taken in weekly intervals. The observations are to be made based on the following criteria.

Seed Germination: Seed germination and early seedling growth are quite sensitive to changing environmental conditions. The germination performance and growth rate of seedlings are therefore often used to access the abilities of plant tolerance to metal elements. The higher concentrations of heavy metals inhibit seed germination and early growth of *Pisum sativum*, mung bean, and mustard seedlings significantly compared to control. Since seed germination is the first physiological process affected by toxic elements, the ability of a seed to germinate in a medium containing any metal element would be a direct indicator of its level of tolerance to this metal. Hence the first observation to take is the measure of germination time.

Root: In plants, roots are the first organs to come into contact with toxic elements and they usually accumulate more metals than shoots. The inhibition of root elongation appears to be the first visible effect of metal toxicity. Root elongation can be reduced by either the inhibition of root cell division and/or the decrease of cell expansion in the elongation zone. Since inhibition of root elongation appears to be the first visible effect of metal toxicity, the root length can be used as an important tolerance index. The second and important observation of our project is to measure the root length that is root elongation.

Shoot: The metal elements adversely affect the plant height and shoot growth as well. The reduction in plant height might be mainly due to reduced root growth and regulation of lesser nutrients and water transport to the Ariel part of the plant. Another observation is that stem length and its growth.

Leaf : A healthy leaf growth, area growth, and total leaf number contribute to crop yield. There appears a reduction in leaf area and leaf dry weight due to heavy metals. The effect of heavy metals results in a reduction in the several leaves of the plant than its usual condition. Measuring the number of leaves and the size of leaves contribute to another observation. The different colors of the leaves also make sense of the effect of metals added to the soil.

For current research and investigation, three agriculture crop plant species are selected *i.e.*, Pea, Mustard, and Mung bean plant have been carefully chosen. As we sowed 5 seeds of each plant, we have seen that the 2 of each are to be germinated successfully under the controlled condition. The sizes regarding the pea plant are noted to be 21 cm of root length while the shoot is recorded to 12 cm and the number of leaves is counted as 10.

The root length of the mung bean plant is seen 32 cm and the shoot length measured to 5.5 cm while the number of leaves is found to be 5. The mustard plant gave the observations like 3 cm root length and shoot length of 1.16 cm and the 4 leaves are counted under the controlled conditions. The texture for all plants that are pea, mung bean, mustard under the controlled conditions is found normal. The observations made for the selected three plants under precise conditions are labeled beneath:

Table-1. The combined effect of metals on selected plants Root, shoot, and leaves

Parameter / Plant	Pea	Mung bean	Mustard
Root (cm)	21	32	3
Shoot (cm)	12	5.5	1.16
Leaf (Numbers)	10	5	4

Fig. 8. Experimental setup with all plants.

Germination of seed: Germination of seeds started during the first week of the experiment. The germination of seed under the controlled conditions turns out to be approximately equal to the expectations. While the germination of all of these three plants that are pea, mung bean, mustard was nullified in the presence of salts of metals like silver and mercury.

For the pea plant the germination seems to be normal in the presence of copper and lead with all of its concentrations while in the presence of zinc and ferrous it's noticed for only three concentrations are 100 ppm, 200 ppm, and 300 ppm and for the rest of concentration, the germination was observed to be nullified. For the manganese and cobalt, the concentration of 500 ppm was affecting the plant, resulting in no germination.

In the case of the mung bean, copper gives the normal germination for its all concentrations except 500 ppm. In zinc, the germination is observed only for the concentrations 100 ppm and 400 ppm. in the presence of ferrous this plant shows normal germination while for the lead its shows only for the moderate concentration. For the metal's manganese and cobalt, the germination was absent for the concentrations 100 ppm and 500 ppm while was normal for the rest.

Mustard plant seeds were germinated normally for the salt of metal lead, manganese, and ferrous. For the copper salt with a concentration of 100 ppm, there was no germination while for the zinc salt there were no germination for the concentrations 300 ppm, 400 ppm, and 500 ppm. The germination in the presence of cobalt salt was recorded as normal except for the 500-ppm concentration.

I] Observations made for the pea plant : The pea plant is observed to be sensitive to some the metals such as Hg, Ag, and Zn while resistive to Cu, Co, Mn. The observations for various parameters are as follows-

Growth of shoot : The copper metal affects the pea plant when the higher concentration of it is used while for the lower concentration it does not affect the shoot growth adversely. For the lower concentrations of lead and cobalt, the growth of shoot was observed to slightly resemble the controlled conditions but for the higher concentrations, the growth seems to be decreased. The lower concentrations of zinc were observed to be beneficial for the plant as it supports the elongation of the shoot while its higher concentrations seem to be harmful to the same.

The metals like mercury and silver affect the plant growing vigorously as the pea plant does not show any germination in presence of these metals. The pea plant is seeming to be sensitive to manganese while it is slightly affected by the higher concentration of the metal ferrous. The overall observations give us a concept that states- the pea plant is moderately affected by the heavy metals for their different concentrations and hence it is beneficial to choose for the higher yield production in such conditions of soil and environment.

Table-2. The effect of metals on a shoot

Heavy metals	The concentration of heavy metals (ppm)				
	100	200	300	400	500
Cu	11	10	10.5	8	6
Zn	14	13	10.5	-	-
Fe	10.5	9	7	-	-
Hg	9	-	-	-	-
Pb	12	10.5	7	6	5
Co	11.5	10	7	5	-
Ag	-	-	-	-	-
Mn	9	9	8.5	8	-

Growth of root : The copper metal does not affect the pea plant when the moderate concentrations (250 to 400 ppm) of it are used while the lower concentrations as well higher concentrations affect the root growth adversely. For the lower concentrations of lead and cobalt, the growth of root was observed to slightly resemble the controlled conditions but for the higher concentrations, the growth seems to be decreased. The lower concentrations of zinc were observed to be beneficial for the plant as it supports the elongation of the root while its higher concentrations seem to be harmful to the same.

The metals like mercury and silver affect the plant growing vigorously as the pea plant does not show any germination in presence of these metals. The pea plant is seeming to be resistive for the lower concentrations of manganese while it is slightly affected by the lower concentration of the metal ferrous also. In the presence of higher concentrations of both metals that is manganese and ferrous, the seed germination seems to be terminated and hence the root growth is highly affected.

Table-3. The effect of metals on the root

Heavy metals	The concentration of heavy metals (ppm)				
	100	200	300	400	500
Cu	11	22	30	30	15
Zn	24	18	16	-	-
Fe	18	16.4	15	-	-
Hg	30	-	-	-	-
Pb	21	17	13	9	4
Co	19	16	13.2	11	-
Ag	-	-	-	-	-
Mn	29	26	28	27.5	-

Growth of leaves : In the pea plant, we have already discussed the effect of these metals on the shoot and root which gives an indirect indication for the effect on leaves of the same. Copper gives an approximately correct value of leaves concerning controlled ones while leaves are absent in the case of metals like silver and higher concentrations of mercury. The ferrous material's lower concentration leads to the reduction of several leaves while its higher concentration is responsible for the absence of the same. The lead metal does not affect the number of leaves in presence of its concentration. Moderate concentration of zinc and manganese results in the sudden increase in several leaves while the rest indicates the deduction in several leaves.

II] Observations made for the mustard plant: The mustard plant showed normal growth for some of the concentrations of these metals while it was affected by the metals like silver and mercury for even the smallest concentrations.

Growth of shoot: The elongation of the shoot of the mustard plant in the presence of the copper metal seems to be increased which implies that the mustard plant is resistive to the copper metal. The lower concentration of the zinc metal gives a proper growth of shoot while the higher concentration of same

Table-4. The effect of metals on leaves

Heavy metals	The concentration of heavy metals (ppm)				
	100	200	300	400	500
Cu	7	7	8	10	8
Zn	8	10	8	-	-
Fe	4	3	2	-	-
Hg	10	-	-	-	-
Pb	11	11	9	9	6
Co	8	7	6	5	-
Ag	-	-	-	-	-
Mn	7	6	8	8	-

Table-5. The effect of metals on a shoot

Heavy metals	The concentration of heavy metals (ppm)				
	100	200	300	400	500
Cu	3.2	3	2.7	2.13	2.13
Zn	2.13	2.13	-	-	-
Fe	2.3	2	1.2	4.3	2
Hg	1.6	1.3	-	-	-
Pb	1.4	1.7	2.3	2.6	3
Co	2.7	2.3	2.3	1.4	-
Ag	1.2	-	-	-	-
Mn	1.8	1.6	1.4	1.2	1.2

affected the growth highly. The lower concentrations of the cobalt are seeming to be beneficial while the higher give no benefit to the plant. The overall ferrous metal is proved beneficial for the mustard plant while silver and mercury are the most harmful metals for the same. The manganese is coming with no such effect to the plant as the shoot growth observed same as the controlled one. The lower concentration of lead gives the same observations as the controlled one with slight variations while the higher concentrations are proved beneficial.

Growth of root: The root elongation of the mustard plant is seeming to be affected by the copper metal in a good way as it results in the average readings for the lower concentrations and the growth values are increased in case of the higher concentrations. The zinc metal results in a decrease in the root growth with the lower concentrations, while there is no germination, observed hence no roots are seen for the higher concentrations of the same. The mustard plant is recorded to be not affected by the ferrous metal. The metals mercury and silver result in no germination of the plant except for some concentration of the same metal. The metals manganese and cobalt are recorded as the beneficial one while the lead cause slight harm to the plant root growth.

Growth of leaves: In the pea plant, we have already discussed the effect of these metals on the shoot and root which gives an indirect indication for the effect on leaves of the same. From the visual observation taken from the experimental setup, we can say that copper metal is proved to be beneficial for the leave of the mustard as it gives approximately equal values of the same as compared to the controlled one.

The zinc metal turns out to be a harmful one as its higher concentration result in the termination of plant growth. In the presence of heavy metals like silver and mercury the left growth seen is equal to be noon. The metals like lead and cobalt do not harm the leaves of this plant. The moderate concentration of manganese results in the average leave growth while its lower and higher concentrations indicate the formal increase in the same.

Table-6. The effect of metals on the root

Heavy metals	The concentration of heavy metals (ppm)				
	100	200	300	400	500
Cu	3	3.6	3.6	4	4.5
Zn	1.9	2.4	-	-	-
Fe	3.2	3.5	3.8	3.3	3.3
Hg	3	3.4	-	-	-
Pb	2.4	1.5	1.9	2.6	3.2
Co	9.4	8	7.3	8	-
Ag	1.6	-	-	-	-
Mn	4	3	3.2	4.5	5

Table-7. The effect of metals on leaves

Heavy metals	The concentration of heavy metals (ppm)				
	100	200	300	400	500
Cu	4	4	5	4	4
Zn	2	5	-	-	-
Fe	5	5	3	4	2
Hg	4	-	-	-	-
Pb	5	3	3	2	4
Co	2	2	1	2	-
Ag	4		-	-	-
Mn	5	4	3	6	5

Table-8. The effect of metals on a shoot

Heavy metals	The concentration of heavy metals (ppm)				
	100	200	300	400	500
Cu	5.5	5	4	3.2	-
Zn	5	-	-	5.5	-
Fe	6	3	4.5	5.4	5
Hg	-	-	-	-	-
Pb	-	5.4	5.4	3	-
Co	5	5.4	-	-	5.4
Ag	5.2	5	-	-	-
Mn	5	5.5	-	-	4

III] Observations of Mung bean plant :

Growth of shoot: The shoot growth of the mung bean plant is nullified in the presence of metals, silver, and mercury while in the presence of ferrous it seems to be not affected. The lower concentration of the manganese does not affect much the shoot growth of the plant but the higher concentration of the same does. The moderate concentration of lead gives the average value of the shoot growth while the lower and the higher concentration of it gives no growth. As we increase the concentration of the metal copper the shoot growth decreases concerning it.in the case of zinc, only some concentrations showed germination hence the mung bean plant is proved to be sensitive to this metal. The cobalt results in the average growth of the shoot of mung bean. (Figs 10-17).

Growth of root: As proved to be harmful metal to the growth of the mung bean plant, the metals silver and mercury inhibit the growth of the roots. The ferrous metal affects the plant in such a way it results in a slight decrease in root length. The metal zinc gives the desired result for only some of its concentrations while others nullify the growth of the plant. Except for the lower concentration of copper, the higher ones decrease the growth of the roots. The moderate concentrations of the lead give us the desired results while in the case of cobalt the lower concentrations give the same. The metal manganese gives the decrease in the length of root for the lower concentration while it fully nullified the germination in case of the moderate as well as a higher concentration of it (Figs 18-33).

Growth of leaves: In the mung bean plant, we have already discussed the effect of these metals on the shoot and root which gives an indirect indication for the effect on leaves of the same. The metals like silver and mercury caused an effect that tends to the absence of the plant growth hence the leaves. The manganese leads to an increase in the number of leaves in the presence of its lower and higher concentration while the leaves are absent in the moderate concentration. Ferrous metal is seemed to be overall beneficial to this plant as it tends to a visibly increase in several leaves. The zinc metal causes the increase in leaves when it is used in lower concentrations while giving the opposite result regarding its higher concentrations. Copper metals proved as the beneficial one to this plant as it has seen several leaves.

Table-9. The effect of metals on the root

Heavy metals	The concentration of heavy metals (ppm)				
	100	200	300	400	500
Cu	30	27	25	13	-
Zn	30	-	-	28	-
Fe	15	12.5	21	19	22
Hg	-	-	-	-	-
Pb	-	32	30	4	-
Co	25	22	-	-	9
Ag	28	26	-	-	-
Mn	19	17	-	-	9

Table-10. The effect of metals on leaves

Heavy metals	The concentration of heavy metals (ppm)				
	100	200	300	400	500
Cu	0	8	5	11	6
Zn	8	-	-	7	-
Fe	7	5	8	8	4
Hg	8	0	0	0	0
Pb	-	8	7	2	0
Co	6	7	-	-	7
Ag	8	-	-	-	-
Mn	9	6	-	-	8

Table-11. Guideline for a safe limit of heavy metals

Sample	Standards	Cd	Cu	Pb	Zn	Mn	Ni	Cr
Agricultural soil (pg CI)	Indian standard Awashthi [2] WHO / FAO [3]	3-6	135-270	250-500	300-600	—	75-150	—
European Union standards (EU 2002)	3	140	300	300	75	150		

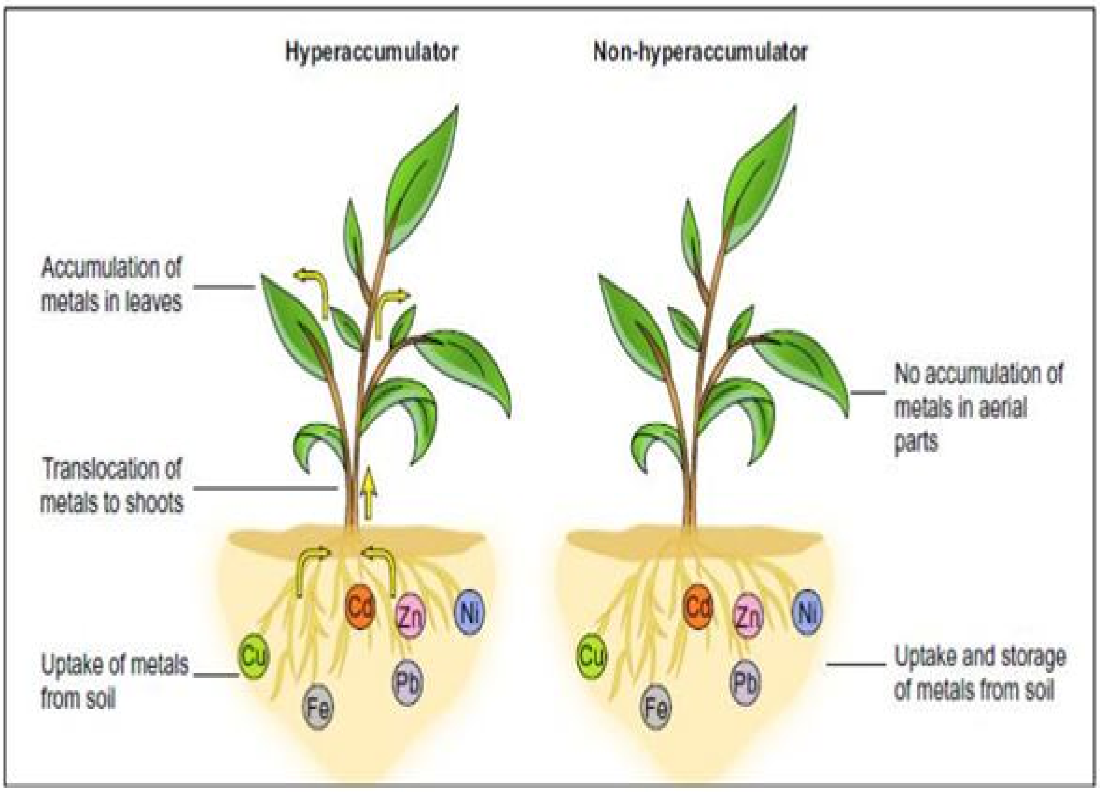

Fig. 9. How hyperaccumulators are different from non-hyper accumulators. The hyperaccumulators allow heavy metal storage in their aboveground parts, whereas non-hyper accumulators store heavy metals in their below-ground organs. Ghori *et al.*,[4].

I] Growth of shoot of the plants

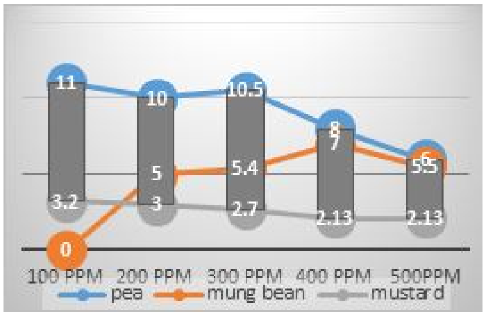

Fig. 10. Showing cumulative effects of Cu

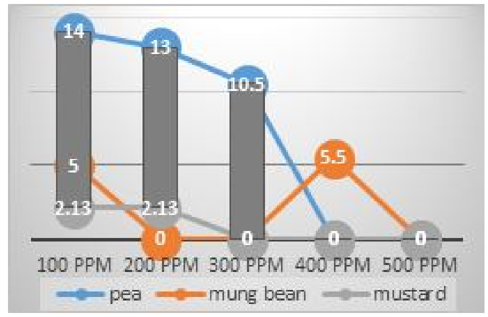

Fig. 11. Graph expressing effects of Zn

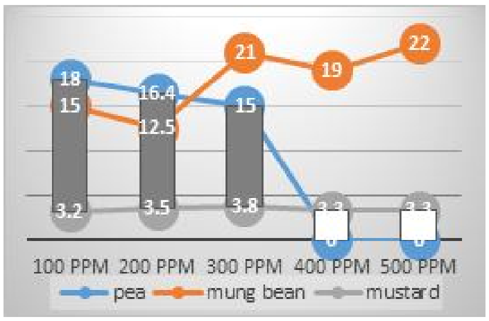

Fig. 12. Graph stating effects of Fe

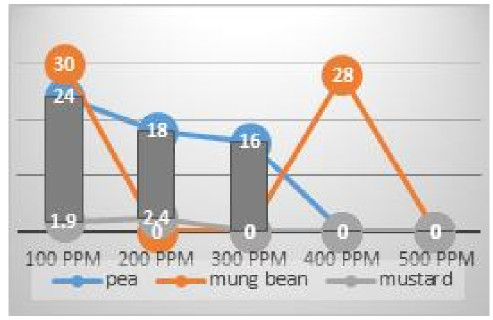

Fig. 13. Showing effects of Hg

Fig. 14. Chart stating effects of Pb

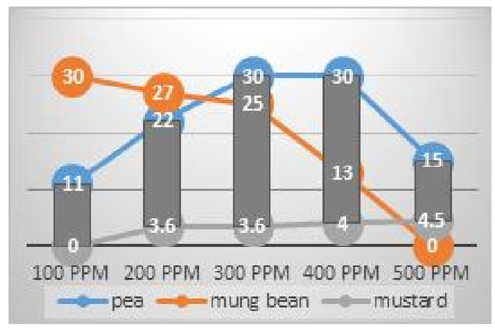

Fig. 15. Graph expressing effects of Co

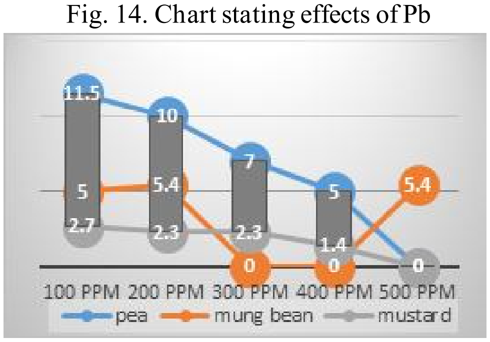

Fig. 16. Graph expressing effects of Ag

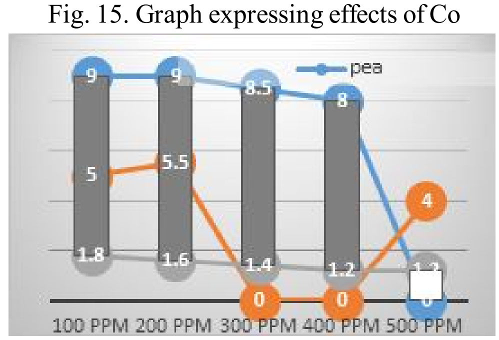

Fig. 17. Showing the effects of Mn

II] Growth of root on the plants

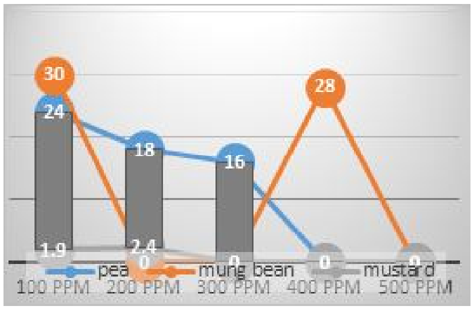

Fig. 18. Showing effects of Cu

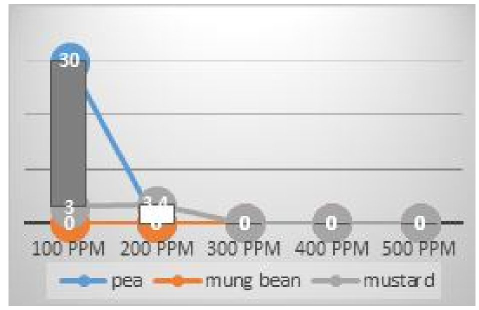

Fig. 19. Showing effects of Zn

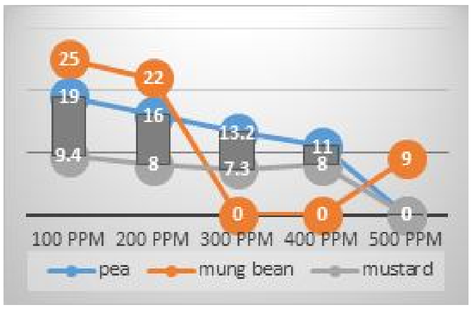

Fig. 20. Showing effects of Fe

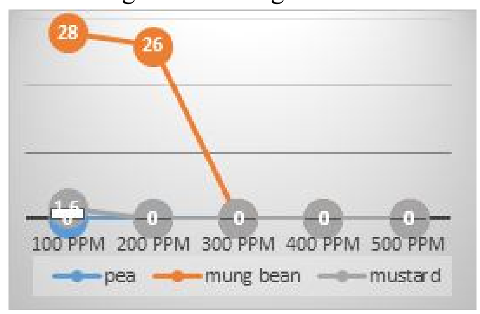

Fig. 21. Showing effects of Hg

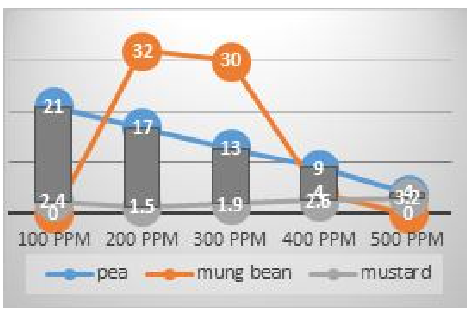

Fig. 22. Graph expressing effects of Pb

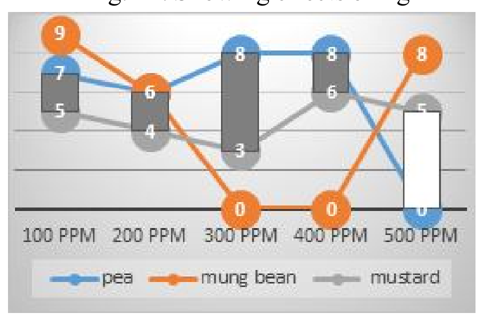

Fig. 23. Showing effects of Co

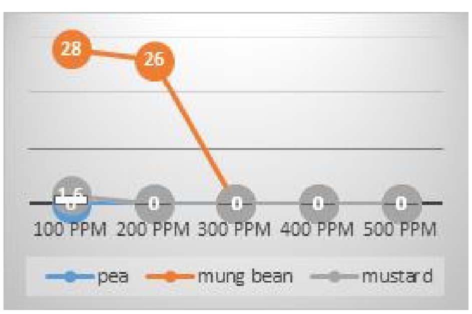

Fig. 24. Graph expressing effects of Ag

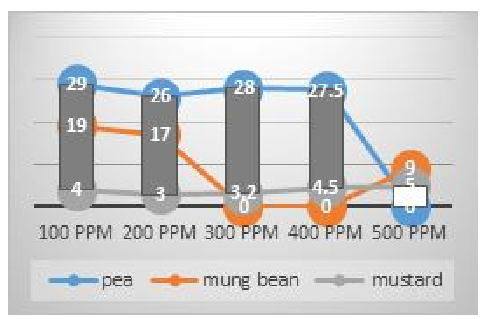

Fig. 25. Showing effects of Mn

III] Growth of leaf of the plants

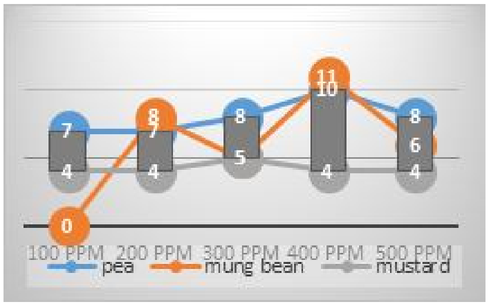

Fig. 26. Graph expressing effects of Cu

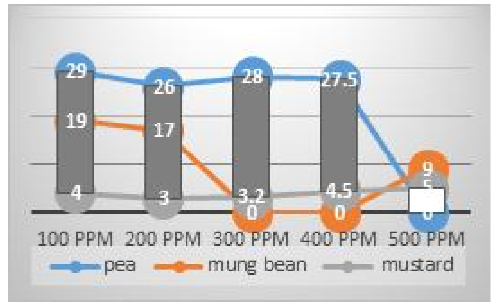

Fig. 27. Expressing effects of Zn

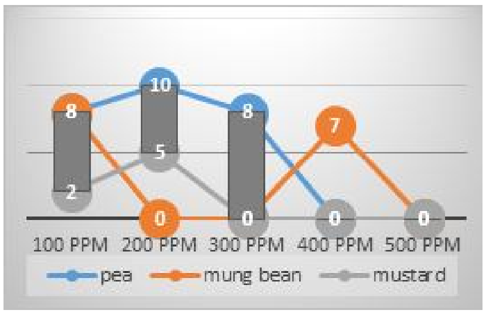

Fig. 28. Graph expressing effects of Fe

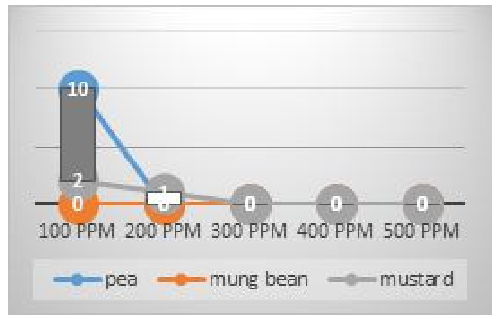

Fig. 29. Graph expressing effects of Hg

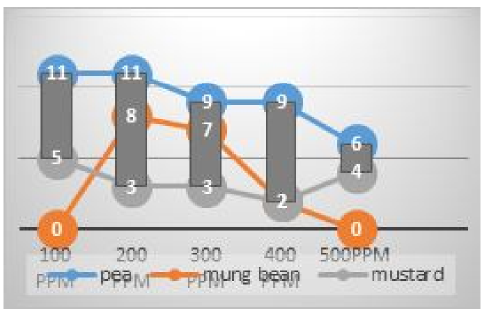

Fig. 30. Graph showing effects of Pb

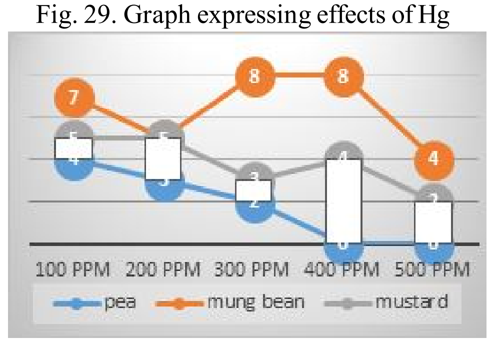

Fig. 31. Graph expressing effects of Co

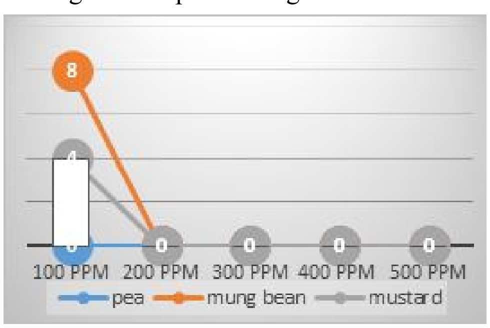

Fig. 32. Graph expressing effects of Ag

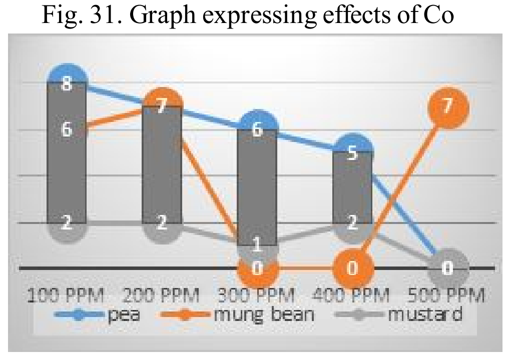

Fig. 33. Graph expressing effects of Mn

Several heavy metal elements are essential for the biological and physiological functions of plants, including biosynthesis of proteins, nucleic acids, growth substances, synthesis of chlorophyll and secondary metabolites, stress tolerance, the structural and functional integrity of various membranes, and other cellular compounds. However, beyond permissible limits, these metal elements become toxic depending upon the nature and species of metal and plants.

Metal Toxicity May Inhibit Electron Transport That Reduces CO_2 fixation and leads to chloroplast disorder. IT CAN Influence the Plant Growth by Producing Free Radicals and Ros, Which Represents a Throat of Constant Oxidative Damage Caused by Emptying of Important Cell Components. Visible Symptoms of Metal Toxicity Include Drying Old Leaves, Weapons, Young Leaf Necrosis, Recession, Shrinking, and Reduced Yield.

In Addition, Heavy Metal Stress Can Induce a Series of Events in Plants, Resulting in A Reduced Size and Size of the Blade, The Cavity Size and The Resistance Change of the Blade Roller and Blades, and Higher Roots. However, Systems Use Complex Methods (Perception, Transduction, and Stress Adjusted Propagation) and Several Non-Enzymatic and Enzymatic Mechanisms, Search AS Activating Cells to Modules Their Metabolism SOD, POD, CAT, AND APX.

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