

IB Extended Essay

Biology

Research on the effects of varying Zn^{2+} solution concentrations on the growth rate of terrestrial plant *Cicer arietinum* L. (Chickpea) measured in terms of length

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Abstract

Pollution is a big problem in today's world. Zinc deposition in nature can cause toxic effect for living organisms and human activity is big source of zinc output. This experiment focused on effects zinc deposition and dealt with the research question, "How is the growth (irreversible change in size) of *Cicer arietinum* L. (Chickpea) in terms of height (cm) effected by different concentrations of Zn^{2+} solutions mixed different groups while the soil quality, pH, temperature and pressure is tried to be constant for all groups?" Would zinc increase of decrease plant growth? How would it affect photosynthesis? Scope of this experiment is limited to terrestrial plants and the effects of zinc given in zinc sulfate form. Results may not be valid for aquatic plants and zinc given in different forms and mixed with other materials. The plant used in this experiment was *Cicer arietinum* L. (Chickpea). 10 mL of solutions having different concentrations of zinc were added once two days to plant samples and stem lengths were recorded daily. Five groups were tested, they were watered, 0g /10 mL, 0.25 g /10 mL, 0.50 g /10 mL, 0.75 g /10 mL and 1.00 g /10 mL for groups 1, 2, 3, 4 and 5 respectively. The samples were observed for 20 days and their growths were measured.

The results showed that there was a clear decline in growth as the zinc concentrations increased. There was significant growth difference present between the groups. The results of this experiment supported my hypothesis that stated there would be significant growth difference caused by zinc deposition and lead to the conclusion that high quantities of zinc has a toxic effect and had a negative effect on plant growth.

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Research on the effects of varying Zn^{2+} solution concentrations on the growth rate of terrestrial plant *Cicer arietinum* L. (Chickpea) measured in terms of length

Introduction

The first time it was a daunting task for me to select a topic that could be investigated seriously. I had lots of interest areas in biology but the experiments were very hard to perform. One day, I saw a program on TV about the use of hormones, fertilizers and various minerals in agriculture and also pollution's effects on plants. It was particularly an interesting subject for me and I based my study on that area.

I researched on the substances and minerals that effect plant growth. Zinc is required for growth of the plants because it is a very important cofactor that works with various types of enzyme classes such as lyases, transferases, hydrolases, oxidoreductases, isomerases, and ligases.¹ It is also essential for the transformation of carbohydrates and regulates sugar consumption.² Zinc deficiency has negative effects such as reduced protein and starch production in tomato.³ Zinc is essential but excess of it has a toxic effect on living organisms.^{4, 5} This toxicity is seen in contaminated soils because of mining and other urban activities.⁶ It is hard to determine the optimum amount of zinc since zinc toxicity tolerance varies even in the same specie.⁷ It is recorded that plants show toxicity symptoms when the zinc concentration at leaf is above 300 mg Zn per kg dry weight.⁵

¹ Webb, EC. *Enzyme nomenclature, recommendations of the Nomenclature Committee of the International Union of Biochemistry and Molecular Biology*.

New York: Academic Press, 1992.

² "Plant Nutrients." *Kids World - Plant Nutrition*. Brought by NCDA&CS. Date of access 07 September 2010. <<http://www.ncagr.gov/cyber/kidswrld/plant/nutrient.htm#Zinc>>

³ Hoagland, DR. *Lectures on the inorganic nutrition of plants*. 2nd ed. Waltham: Chronica Botanica Company, 1948.

⁴ Fosmire, Gary J. "Zinc toxicity." *The American Journal of Clinical Nutrition*. 29 Mar 1990. Date of access 07 Sep 2010. <<http://www.ajcn.org/content/51/2/225.full.pdf>>

⁵ Chaney, RL. "Zinc phytotoxicity." Ed. A.D. Robson. *Zinc in soil and plants*. Dordrecht: Kluwer Academic Publishers, 1993. 135–150.

⁶ Kahvecioğlu, Özge; Güldem Kartal, Aybars Güven, and Servet Timur. "Metallerin Çevresel Etkileri-I (Trans: Environmental Effects of Metals-I)." *UCTEA Chamber of Metallurgical Engineers*. 13 Mar 2009. Date of access 25 Sep 2010. <http://www.metalurji.org.tr/dergi/dergi136/d136_4753.pdf>

⁷ Davies, BE. "Radish as an indicator plant for derelict land – uptake of zinc at toxic concentrations." *Communications in Soil Science and Plant Analysis*. 1993.

Plants receive Zinc from the soil. A source of zinc is the parent rocks' physical and chemical weathering; Lithosphere comprises 70–80 micrograms of zinc per gram, sedimentary rocks have 10–120 micrograms of zinc per gram.^{8, 9, 10} Another natural source of zinc in soil is atmospheric and biotic processes that usually takes place on the surface of the earth.⁸ There is also large amounts of zinc input into soil by human activities such as mining and industrial activities.¹¹

In later research, I decided to work on the specie *Cicer arietinum* L. (Chickpea). Chickpea is from the *Plantae* kingdom, *Tracheobionta* subkingdom, *Spermatophyta* superdivision, *Magnoliophyta* division, *Magnoliopsida* class, *Rosidae* subclass, *Fabales* order, *Fabaceae* family, *Faboideae* subfamily and *Cicer* genus.¹² Chick pea is grown in temperate, sub-tropical and tropical regions.¹³

Cicer arietinum L. (Chickpea) seeds are used in many dishes served in various ways. It can be fried, roasted, boiled or eaten fresh. Its can be served as a usual snack, condiment or sweet. Also *Cicer arietinum* L. (Chickpea) seed separated from its seed coat can be used in soups and as flour for snacks, *Cicer arietinum* L. (Chickpea) seeds are very nutritive because of their high protein content reaching 25.3-28.9 %.^{14, 15} Also The Vegetarian Society states that a 200g single serving of chickpeas contain approximately 2.8 mg zinc, which makes it a good source of zinc which is a very important mineral for humans.¹⁶

⁸ Friedland AJ. "The movement of metals through soils and ecosystems." *Heavy metal tolerance in plants: evolutionary aspects*. Ed. A.J. Shaw. Boca Raton: CRC Press, 1990. Pages 7–19.

⁹ Barak, P., and P.A. Helmke. "The chemistry of zinc." *Zinc in soil and plants*. Ed: AD Robson. Dordrecht: Kluwer Academic Publishers, 1993. Pages 1–13.

¹⁰ Alloway, B.J. *Heavy metals in soils, 2nd edition*. London: Blackie Academic & Professional, 1995.

¹¹ Nriagu, JO. "A history of global metal pollution." 1996. *Science* 272: 223–224.

¹² "*Cicer arietinum* L." *USDA – Natural Resources Conservation Service, Plant Database*. Date of access 05 Sep 2010. <<http://plants.usda.gov/java/profile?symbol=CIAR5>>

¹³ Malhotra, R.S., R.P.S. Pundir and A.E. Slinkard. "Genetic resources of chickpea." *The Chickpea*. Ed. M.C. Saxena and K.B. Singh. Aberystwyth: C.A.B. International Cambrian News Ltd, 1987. Pages 67-81.

¹⁴ Hulse, J.H. "Nature, composition and utilization of grain legumes." *Uses of tropical Legumes: Proceedings of a Consultants' Meeting, 27-30 March 1989*. Patancheru: ICRISAT Center. ICRISAT, 1991. Pages 11-27.

¹⁵ Muehlbauer, F.J., Abebe Tulu, contributors. "*Cicer arietinum* L." *Purdue University*. 1997.

<<http://www.hort.purdue.edu/newcrop/cropfactsheets/chickpea.html>>

¹⁶ *Vegetarian Society*. Date of access 29 Sep 2010. <<http://www.vegsoc.org/info/zinc.html#diet>>

Turkey is one of the top producers of *Cicer arietinum* L. (Chickpea), being the 3rd biggest producer of it in 2009, producing 562564 tones that year.¹⁷ This reflects the economical importance of chickpea agriculture in Turkey.

A couple of *Cicer arietinum* L. (Chickpea) seeds were planted before the actual experiment to see how it would grow and check if it was suitable for my experiment. The seeds germinate in a couple of days and grow very fast. Also it has a straight stem that makes length measurements easier. So *Cicer arietinum* L. (Chickpea) is a very suitable specie for this particular experiment.

This research is narrowed down on the effects of different zinc solution concentrations on terrestrial plant *Cicer arietinum* L. (Chickpea). Zinc in solutions was obtained from mixing zinc sulfate with water. The results obtained from this experiment may not apply directly for other types of plants such as aquatic and epiphytic plants.

This experiment will focus on the research question:

“How is the growth (irreversible change in size) of *Cicer arietinum* L. (Chickpea) in terms of height (cm) effected by different concentrations of Zn^{2+} solutions added to different groups while the soil quality, pH, temperature and pressure is tried to be constant for all groups?”

The importance of this research topic is to demonstrate the effects of pollution mainly due to mining activities. This kind of pollution may be harmful for crops and effect agriculture. Changes in agriculture directly affect human beings since nutrition is an essential part of our lives. Researching the effects of zinc – a substance that could effect plant growth – on terrestrial plant *Cicer arietinum* L. (Chickpea) could represent a model for the effects of zinc deposition in nature and its effect on agriculture.

¹⁷ “FAOSTAT > Production > Crops.” *FAOSTAT - Food and Agriculture Organization of the United Nations*. Date of access 25 Oct 2010. <<http://faostat.fao.org/site/567/DesktopDefault.aspx?PageID=567#ancor>>

Hypothesis

Zn is an essential substance for a plant. Plants require a minimum amount of zinc for its growth, but excess zinc could be toxic as explained in the introduction. By looking at the proportions used in this experiment, it is possible to predict that zinc toxicity would be observed and growth of the plant growth would be inhibited. Quantities used in this experiment are high above micrograms, which in this case could be considered excess for a plant. If any toxic effect occurs, it would imply that changing zinc quantities would affect plant growth. As a result it can be hypothesized that **“Different concentrations of Zn²⁺ solutions will affect the growth rate of *Cicer arietinum* L. (Chickpea)”**. The hypothesis implies a few possible outcomes; zinc can either increase or inhibit growth of the plant. My prediction is that zinc would show its toxic effect and inhibit plant growth.

Method Development and Planning

A suitable method should be designed for the experiment to be performed. There are lots of variables that could affect the results so all the variables should be kept constant except the independent variable which in this case is the amount of zinc we put in the soil. The dependent variable in this case is the growth of *Cicer arietinum* L. (Chickpea) measured by height of the plant (in cm). It will change according to the independent variable. Other variables that could affect the results are given below. These variables are to be kept constant to observe the effect of different zinc concentrations.

- **Watering quantity**
- **Water source**
- **Watering time**
- **Watering technique**

- **Zinc source**
- **Zinc adding time**

- **Soil quantity**
- **Soil source (composition)**
- **Height of soil (under and on) the seed**
- **Suppression of soil**
- **Cup size, width, height (cups must be identical)**

- **Similar seed weight, color, size, appearance (genetic variation)**
- **Seed planting height (vertical)**
- **Seed planting place (horizontal)**
- **Room temperature**
- **Room pressure**
- **Humidity level**
- **Surrounding air**
- **Light exposure**
- **Time interval and measurement time**

Water is obviously an essential material for plant growth. Plants are made up of 90% water and water is used many important tasks such as:

1. Being the main component of transpiration and photosynthesis.
2. Keeping the turgor pressure that holds the plant erect by inflating the cells.
3. Working as a solvent to carry minerals and organic material through the plant.
4. Being the source of pressure to move roots through the soil.
5. Providing the required medium for biochemical reactions to take place.¹⁸

Because water is an essential material for growth, it has to be added at the same amounts for each test subject. 10 mL of water should be given once two days to each test subject at 20:30 from a 20 mL (± 0.5 mL) injector. Subjects should be watered at 20.30 because during daytime water would evaporate and it would be less effective.¹⁹ Watering technique is important since watering the edges of the cup would be less beneficial for water absorption because the seed is at the center. Watering should be done by starting from the center and watering the cup homogeneously. Water extraction from the airtight cups must be quickly done as possible because water would evaporate increasing the concentration of the solution.

While watering the plants spreading water equally is an important aspect since it may interfere with the growth process. The same water- Karacakaya[®] Natural Spring Water should be used through the whole experiment. An important point is that it does not contain zinc. Chemical analysis of the water is given at table 1.

¹⁸ Whiting, David, Michael Roll and Larry Vickerman. "Plant Growth Factors: Water." *Colorado State University Extension*. Date of access 17 Sep 2010. <<http://www.cmg.colostate.edu/gardennotes/144.pdf>>

¹⁹ BBC Worldwide. "How to water your plants." *Gardeners' World.com*. Date of access 17 Sep 2010. <<http://www.gardenersworld.com/how-to/projects/water-plants/>>

Chemical properties of the water used in irrigation (Karacakaya® natural spring water)			
Aluminum	17 µg/L	Manganese	0 mg/L
Ammonium	0 mg/L	Smell	Appropriate
Chloride	1.4 mg/L	pH	7.15
C. perifringses	0 in 100 mL	Sulfate	4.92 mg/L
Color	Appropriate	Sodium	6.35 mg/L
Conductivity (at 20°C)	96.2 µS/cm	Taste	Appropriate
Iron	43 µg/L	Blurriness	Appropriate

Table 1: Chemical properties of the water used for irrigation during experiment.

Zinc source for this experiment is zinc sulfate ($ZnSO_4$) because it is the mostly used zinc source in fertilizers.^{20, 21} Zinc is found in nature in many forms but this experiment does not extend to that so only zinc sulfate ($ZnSO_4$) compound is used. Zinc should be added to the subjects at the closest time possible to keep the zinc addition time same for all plants since it can interfere with the results.

Zinc addition before germination may prevent germination. This experiments scope is limited on zincs effect on growth, not germination. Zinc addition should start after observing the first green leave of the plant. This means that the plant has started to do photosynthesis and growing on its own.

The composition of soil used in growing plants is very important because plant absorbs the necessary minerals from it. A zinc free soil is required for this experiment since this experiment focuses on zinc deposition, soil containing zinc would affect the results. Güpaş® Özel houseplant soil was used to grow the plants. Its chemical analysis is provided at table 2.

²⁰ Follett, R.H. and D.G. Westfall. "Zinc and Iron Deficiencies" *Colorado State University Extension*. Date of access 12 Sep 2010. <<http://www.ext.colostate.edu/pubs/crops/00545.pdf>>

²¹ Westfall, D.G., M. Amrani, and G.A. Peterson "Water-Solubility of Zinc Fertilizer: Does It Matter?" *International Plant Nutrition Institute*. Date of access 12 Sep 2010. <[http://www.ipni.net/ppiweb/bcrops.nsf/\\$webindex/948276DF7FC729A6852568EF005CE470/\\$file/99-2p18.pdf](http://www.ipni.net/ppiweb/bcrops.nsf/$webindex/948276DF7FC729A6852568EF005CE470/$file/99-2p18.pdf)>

Chemical properties of the soil used in experiment (Güpaş® Özel houseplant soil)
Peat (turf): %80
Organic matter: %20
pH: 6.5 – 7.2
Nitrogen (N): % 0.4 – 1.0
Phosphorus (P ₂ O ₅): 150 – 300 ppm
Potassium (K ₂ O): 600 – 1200 ppm

Table 2: *Chemical properties of the soil used in experiment.*

Some important statements on the brand are that:

“Güpaş® Özel houseplant soil contains all the necessary nutrients in desired level and ideal combinations for plants to grow.”

“In normal conditions Güpaş® Özel houseplant soil provides perfect growth in plants for a long time without fertilization.”

Same type cups must be used for each plant to provide them equal area of growth. White plastic cups were used in this experiment. The cup dimensions are given at diagram 1. (See diagram 1)

5 liters of soil (weighing 2.4 kg) divided to 25 by volume, provides each test subject with 200 mL soil weighing 96 grams. Put the seed between layers of soil. First layer is 7.50 cm high. The seed is put on top of that. Then 2.50 cm of additional soil is put. The same soil quantities should be put for every plant since their roots would be similar. Having different quantities of soil would affect the results. (See diagram 2)

To demonstrate the natural conditions, the soil must not be pressed. It must be left out as it is. Also suppressing the soil would close the air gaps in the soil. With less air present, respiration rate of roots could be affected therefore resulting with less growth.

Seeds should be planted at the horizontal center and vertically 7.50 cm height. Its roots touching the cup surface is an unwanted situation since it doesn't reflect the natural conditions. In natural conditions there wouldn't be any manufactured plastic inside soil. So to minimize contact, the seed is put right at the center because it's the maximum far distance from all the surfaces of the cup

Plants are put at least 10 cm apart to prevent shading or affecting each other. All other room conditions must be similar for plants. The experiment started for all the plants at the same time. All the test subjects are at the same room so the humidity, temperature and air that they are exposed is the same. Light intensity is a factor affecting photosynthesis rate and therefore growth of the plant. Test subjects must be located in the same area with no light receiving differences or shadows shading some plants.

The experiment lasted for 20 days starting on 23 November (Day 1) and ending on 12 December (Day 20). Measurements were taken daily, at the same time. Measurements were taken from 23 November (Day 1) until 12 December (Day 20). If the seed hadn't germinated yet, its length was recorded as 0.00 cm.

Diagrams

Diagram 1: Diagram illustrating the plastic cups used in this experiment.

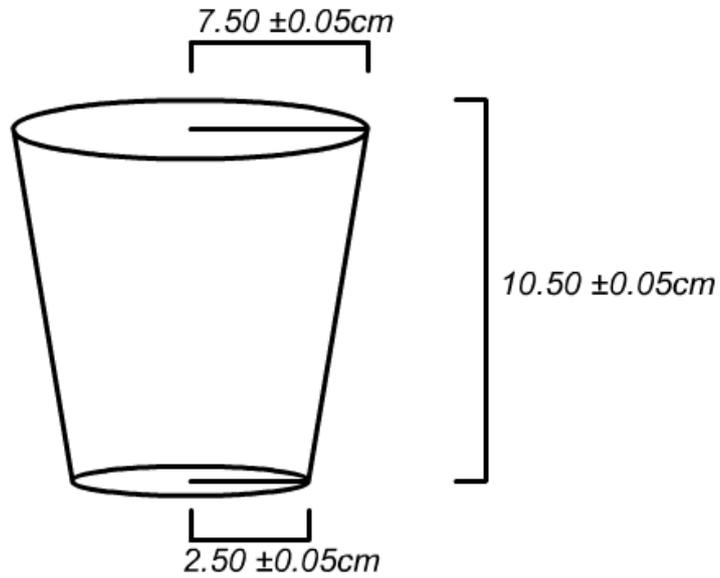


Diagram 2: Diagram illustrating the placing of the seed.

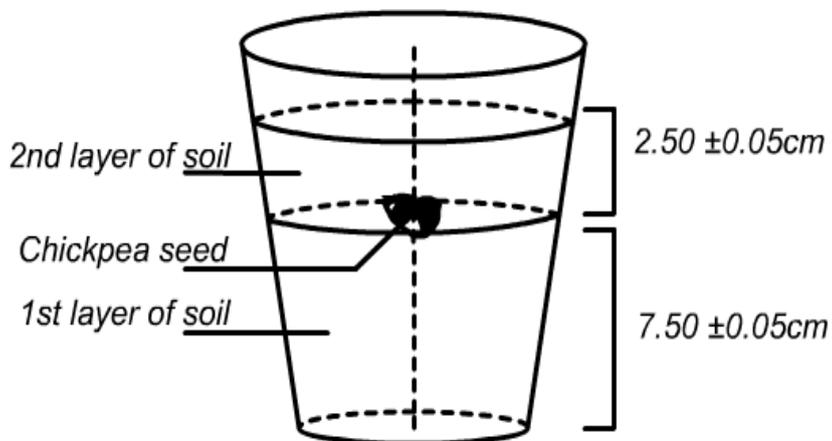


Diagram 3: General setup of the experiment groups, and the quantity of zinc that each plant receives in each group.

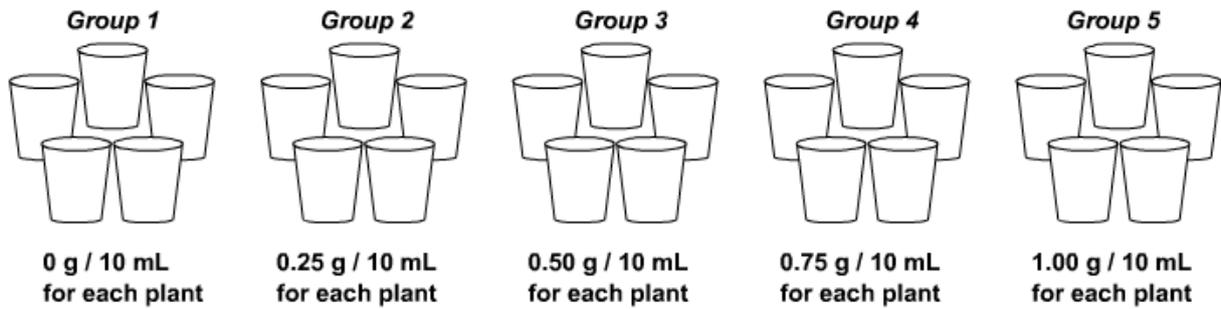


Diagram 4: Length measurement technique for the plant stems.

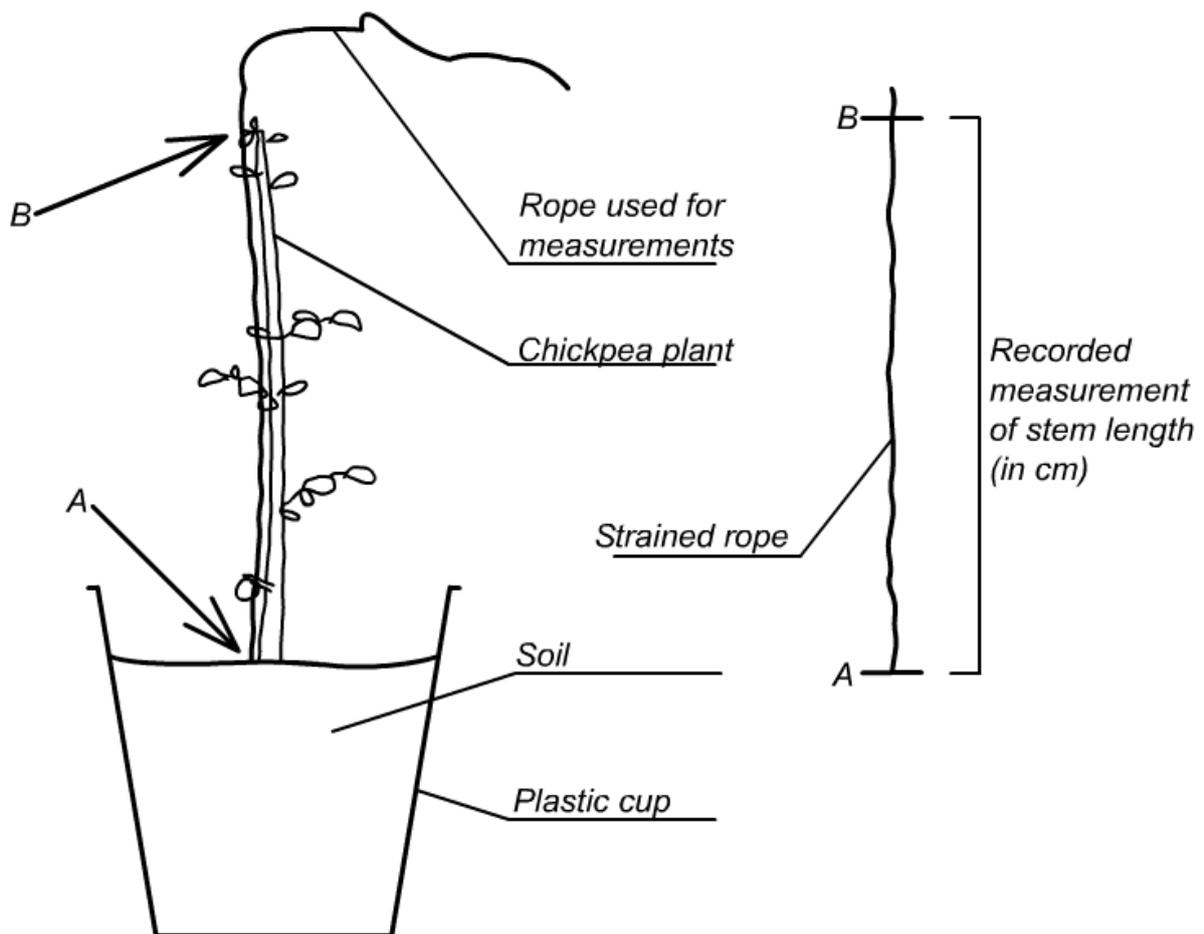
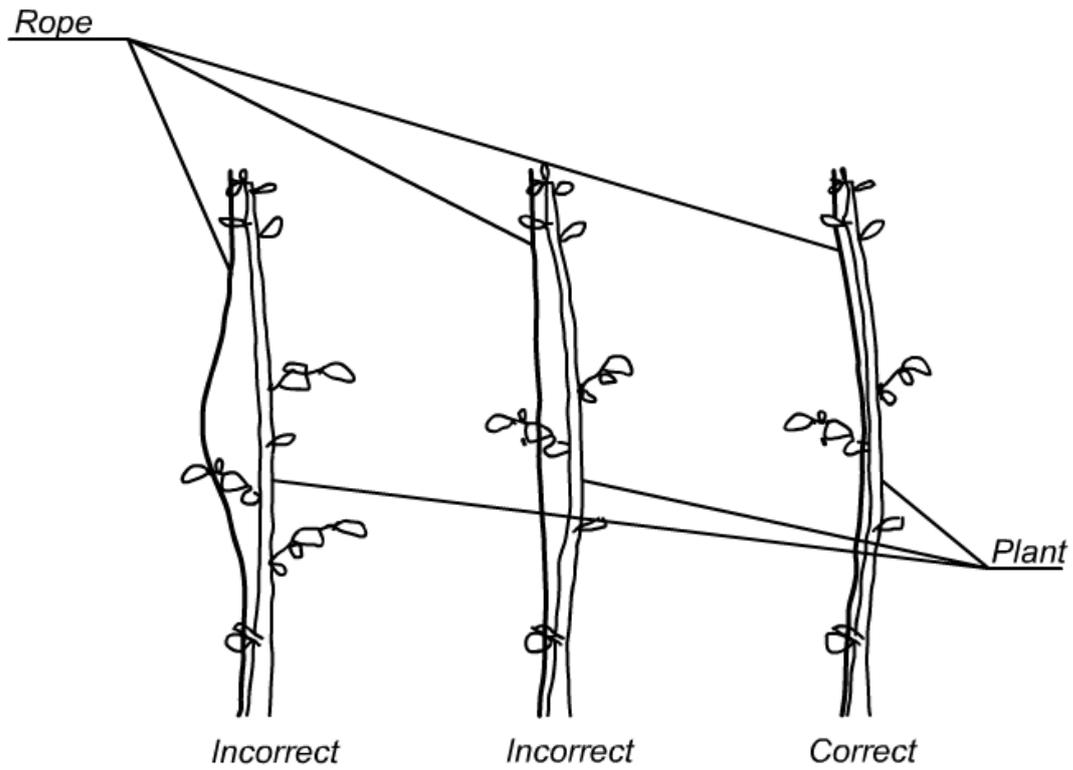


Diagram 5: Diagram showing correct and incorrect measurement techniques.



Materials/Apparatus:

500 mL beaker (± 5 mL)	5 liter Karacakaya [®] natural spring water
<i>Cicer arietinum</i> L. (Chickpea) seeds (X25)	Güpaş [®] Özel houseplant soil (5 liters or 2.4 kg)
20 mL injector (± 0.05 mL)	50 cm ruler (± 0.05 cm)
Digital weight (± 0.001 g)	Rope that is at least 50 cm long
Jars or any airtight container (X4)	Pen
50 mL Graduated cylinder (± 0.05 mL)	Labeling stickers (X30)

Method

1. 25 plastic cups were separated and labeled accordingly:

	Group 1	Group 2	Group 3	Group 4	Group 5
Sample 1	G1S1	G2S1	G3S1	G4S1	G5S1
Sample 2	G1S2	G2S2	G3S2	G4S2	G5S2
Sample 3	G1S3	G2S3	G3S3	G4S3	G5S3
Sample 4	G1S4	G2S4	G3S4	G4S4	G5S4
Sample 5	G1S5	G2S5	G3S5	G4S5	G5S5

Table 3: Labeling system for five samples for each of the five groups. “G” is the abbreviation for group and “S” is the abbreviation for sample. For example the name “G4S2” represents sample 2 in group 4.

2. Concentrations for the zinc solutions are given below. By using the digital weight, measure 0, 25, 50, 75 and 100 grams of zinc (See table 4). Then mix each of them with 1 liter water separately. Wave or shake the container if necessary to completely mix the zinc sulfate and water. Use only Karacakaya® natural spring water while preparing the solutions.

	Group 1	Group 2	Group 3	Group 4	Group 5
Mass Concentration of Zinc solution (g/L)	0	25	50	75	100

Table 4: Mass concentrations of zinc in solutions.

3. When the solutions are prepared, pour them into separate jars or airtight containers. Solutions must be kept at closed systems because water would eventually evaporate increasing the concentration that could affect the results and cause a source of error. 0, 25, 50, 75 and 100 grams of zinc is present in 1 liter (1000 mL) solutions respectively. Every 10 milliliters taken from these solutions would have 0, 0.25, 0.50, 0.75 and 1.00 grams of zinc respectively.
4. Güpaş® Özel houseplant soil is poured into plastic cups. All the cups must be identical. Look at diagram 1 and 2 to have a clearer view. The height of the poured soil should be 7.50 cm. Then the *Cicer arietinum* L. (Chickpea) seed is added. Again a second layer of soil is put on the treat. It should be about 2.50 cm. The final soil height is 10 cm.
5. The plants were watered once for every two days, at 20:30, each time 10 mL water with varying zinc. They were watered using an injector. Every time, only 10 mL water was given regardless with the zinc amount because water quantity is kept constant. The amount of zinc that plants receive in each time of watering is given at table 5.

	Group 1	Group 2	Group 3	Group 4	Group 5
Mass Concentration of Zinc in 10 mL (g / 10 mL)	0	0.25	0.50	0.75	1.00

Table 5: The amount of zinc that each plant in groups receives per watering.

6. Stem lengths were measured at the same time, daily. The length of the plant could be easily measured by using a rope. The end of the rope was held at the base of the plant and the other part of rope is extended to meet the end of the plant. The two points were held, the rope was then strained and the distance between these points were measured by using a ruler. (See diagram 4) Make sure that the rope and stem is closer as possible to each other. A gap may result in wrong measurement. (See diagram 5)
7. Observations were also recorded such as the color of the plants and their structure.

See the general setup of the experiment in diagram 3.

Results and Analysis

		Group 1 (no zinc, watered 10 mL every 2 days)				
		G1S1	G1S2	G1S3	G1S4	G1S5
Stem length of chickpeas measured daily for 20 days (\pm 0.05 cm)	Day 1	1.54	0.00	1.50	0.00	1.77
	Day 2	2.58	1.76	2.70	0.00	2.34
	Day 3	4.24	2.33	4.53	1.62	2.65
	Day 4	7.67	5.62	6.65	2.84	5.70
	Day 5	11.28	9.22	8.42	6.61	10.19
	Day 6	15.23	13.70	12.06	8.31	12.62
	Day 7	17.50	16.20	13.61	10.44	14.58
	Day 8	19.47	18.29	14.30	12.65	15.80
	Day 9	22.05	20.04	14.95	15.02	16.36
	Day 10	24.39	21.06	15.28	17.84	16.51
	Day 11	26.91	22.75	15.68	19.15	18.46
	Day 12	28.58	24.19	16.25	23.49	19.97
	Day 13	30.02	26.05	16.80	24.97	21.34
	Day 14	32.88	28.94	18.15	28.60	23.58
	Day 15	35.32	29.45	20.49	33.75	25.38
	Day 16	37.54	33.61	21.34	35.01	27.22
	Day 17	39.81	35.50	22.66	36.93	29.42
	Day 18	43.15	37.65	25.68	39.45	31.40
	Day 19	46.20	40.57	28.54	42.00	33.56
	Day 20	47.05	41.10	31.20	42.51	35.37

Table 6: Results for group 1 (control group). For abbreviations, G: group, S: sample; GXSY stands for sample number Y in group number X.

		Group 2 (0.25g zinc, watered 10 mL every 2 days)				
		G2S1	G2S2	G2S3	G2S4	G2S5
Stem length of chickpeas measured daily for 20 days (± 0.05 cm)	Day 1	0.00	0.00	0.58	0.00	0.00
	Day 2	0.00	1.16	2.00	1.40	0.00
	Day 3	1.75	1.78	2.59	3.29	0.63
	Day 4	2.66	2.32	4.64	3.95	1.87
	Day 5	4.13	4.44	6.43	5.98	2.48
	Day 6	5.68	6.94	8.27	8.03	4.08
	Day 7	6.13	8.91	9.30	10.59	5.82
	Day 8	6.90	9.32	9.62	11.87	6.94
	Day 9	8.04	10.98	10.87	12.73	8.29
	Day 10	10.02	12.45	11.24	14.50	9.77
	Day 11	12.04	13.21	11.97	15.57	9.89
	Day 12	12.72	13.78	12.83	17.18	10.45
	Day 13	13.98	15.78	14.38	18.76	11.28
	Day 14	14.72	17.24	15.24	19.99	12.07
	Day 15	15.42	18.83	15.76	23.46	14.76
	Day 16	15.84	18.94	18.32	23.76	16.14
	Day 17	16.75	19.34	20.38	24.55	17.52
	Day 18	17.23	20.18	22.22	25.61	17.76
	Day 19	18.39	21.31	23.80	26.13	18.26
	Day 20	18.80	21.49	23.80	26.46	20.75

Table 7: Results for group 2. For abbreviations, G: group, S: sample; GXSY stands for sample number Y in group number X.

		Group 3 (0.50g zinc, watered 10 mL every 2 days)				
		G3S1	G3S2	G3S3	G3S4	G3S5
Stem length of chickpeas measured daily for 20 days (± 0.05 cm)	Day 1	0.00	0.00	0.00	0.11	0.00
	Day 2	0.00	0.00	0.32	0.45	0.95
	Day 3	1.84	0.57	1.55	1.55	2.49
	Day 4	2.21	1.61	2.43	2.56	3.86
	Day 5	2.30	1.90	2.97	3.74	4.28
	Day 6	2.96	2.61	3.27	4.03	4.49
	Day 7	3.22	3.14	3.78	4.73	5.62
	Day 8	4.56	3.87	3.84	6.08	6.29
	Day 9	5.31	4.58	4.29	7.92	6.56
	Day 10	5.88	5.44	4.79	8.90	6.90
	Day 11	5.90	5.74	5.44	9.16	6.43
	Day 12	5.96	6.54	5.86	10.37	7.19
	Day 13	6.57	8.09	5.95	11.22	7.33
	Day 14	6.00	8.89	5.90	11.06	7.59
	Day 15	6.00	9.67	5.90	11.06	7.59
	Day 16	5.92	9.91	5.42	11.06	8.00
	Day 17	5.87	10.23	5.42	10.78	7.85
	Day 18	5.51	10.54	5.42	10.64	7.64
	Day 19	5.51	10.54	5.42	10.64	7.60
	Day 20	5.51	9.98	5.28	10.64	7.44

Table 8: Results for group 3. For abbreviations, G: group, S: sample; GXSY stands for sample number Y in group number X.

		Group 4 (0.75g zinc, watered 10 mL every 2 days)				
		G4S1	G4S2	G4S3	G4S4	G4S5
Stem length of chickpeas measured daily for 20 days (± 0.05 cm)	Day 1	0.00	0.00	0.24	0.00	0.00
	Day 2	0.15	0.00	0.50	0.00	0.49
	Day 3	0.63	0.00	0.83	0.78	1.07
	Day 4	1.19	0.22	1.30	1.27	1.67
	Day 5	1.60	0.77	2.32	1.87	1.98
	Day 6	2.32	1.00	2.92	2.42	2.40
	Day 7	3.39	1.59	3.05	2.89	2.57
	Day 8	3.82	1.78	3.66	3.35	3.27
	Day 9	5.21	2.54	4.53	3.84	4.40
	Day 10	5.21	2.74	4.88	5.84	4.82
	Day 11	5.23	3.92	5.78	5.84	5.52
	Day 12	5.27	4.95	5.99	6.18	6.10
	Day 13	5.27	5.63	6.17	6.19	6.10
	Day 14	5.27	5.63	6.54	6.19	6.10
	Day 15	5.39	6.23	6.77	6.31	6.47
	Day 16	5.39	6.43	6.77	6.31	6.47
	Day 17	5.39	6.53	6.81	6.31	6.47
	Day 18	4.49	6.53	6.81	5.71	6.47
	Day 19	4.49	6.22	6.81	5.71	6.33
	Day 20	4.49	6.22	6.81	5.71	6.33

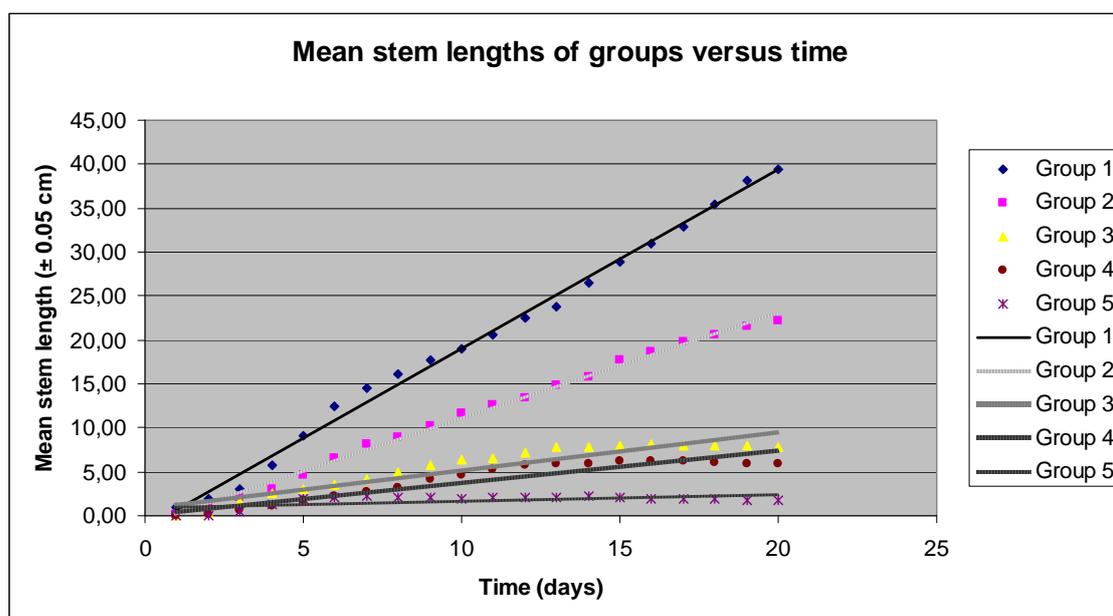
Table 9: Results for group 4. For abbreviations, G: group, S: sample; GXSY stands for sample number Y in group number X.

		Group 5 (1.00g zinc, watered 10 mL every 2 days)				
		G5S1	G5S2	G5S3	G5S4	G5S5
Stem length of chickpeas measured daily for 20 days (± 0.05 cm)	Day 1	0.00	0.00	0.00	0.00	0.00
	Day 2	0.00	0.00	0.00	0.16	0.00
	Day 3	0.00	1.05	0.88	0.34	0.00
	Day 4	0.75	1.84	2.04	1.40	0.11
	Day 5	1.81	2.48	2.46	2.05	0.43
	Day 6	1.40	2.57	2.86	2.18	1.19
	Day 7	2.03	2.57	2.95	2.18	1.19
	Day 8	1.85	2.38	2.46	2.28	1.62
	Day 9	1.04	2.16	2.38	2.93	1.77
	Day 10	0.94	2.16	1.89	3.05	1.91
	Day 11	0.98	2.24	1.89	3.06	2.19
	Day 12	1.02	2.30	1.89	3.29	2.23
	Day 13	1.02	2.30	1.89	3.29	2.25
	Day 14	1.02	2.30	1.89	3.35	2.25
	Day 15	1.02	2.30	1.54	3.35	2.25
	Day 16	1.02	2.17	1.54	3.11	2.13
	Day 17	0.84	2.17	1.54	3.11	2.13
	Day 18	0.84	2.17	1.54	3.11	1.61
	Day 19	0.84	2.17	1.48	2.91	1.61
	Day 20	0.84	2.17	1.48	2.91	1.61

Table 10: Results for group 5. For abbreviations, *G*: group, *S*: sample; *GXS_Y* stands for sample number *Y* in group number *X*.

			Group 1 (0g/10 mL)	Group 2 (0.25g/10 mL)	Group 3 (0.50g/10 mL)	Group 4 (0.75g/10 mL)	Group 5 (1.00g/10 mL)
Mean stem lengths of chickpeas among groups (± 0.05 cm)	23-Nov	Day 1	0.96	0.12	0.02	0.05	0.00
	24-Nov	Day 2	1.88	0.91	0.34	0.23	0.03
	25-Nov	Day 3	3.07	2.01	1.60	0.66	0.45
	26-Nov	Day 4	5.70	3.09	2.53	1.13	1.23
	27-Nov	Day 5	9.14	4.69	3.04	1.71	1.85
	28-Nov	Day 6	12.38	6.60	3.47	2.21	2.04
	29-Nov	Day 7	14.47	8.15	4.10	2.70	2.18
	30-Nov	Day 8	16.10	8.93	4.93	3.18	2.12
	1-Dec	Day 9	17.68	10.18	5.73	4.10	2.06
	2-Dec	Day 10	19.02	11.60	6.38	4.70	1.99
	3-Dec	Day 11	20.59	12.54	6.53	5.26	2.07
	4-Dec	Day 12	22.50	13.39	7.18	5.70	2.15
	5-Dec	Day 13	23.84	14.84	7.83	5.87	2.15
	6-Dec	Day 14	26.43	15.85	7.89	5.95	2.16
	7-Dec	Day 15	28.88	17.65	8.04	6.23	2.09
	8-Dec	Day 16	30.94	18.60	8.06	6.27	1.99
	9-Dec	Day 17	32.86	19.71	8.03	6.30	1.96
	10-Dec	Day 18	35.47	20.60	7.95	6.00	1.85
	11-Dec	Day 19	38.17	21.58	7.94	5.91	1.80
	12-Dec	Day 20	39.45	22.26	7.77	5.91	1.80

Table 11: Mean stem lengths of chickpeas among groups. Averages from tables 6, 7, 8, 9 and 10.



Graph 1: Graphical indication of average length given at table 11.

	Group 1	Group 2	Group 3	Group 4	Group 5
Mean	19.9765	11.665	5.468	4.0035	1.6985
Standard Error	2.706948	1.607895	0.618765	0.510436	0.156614
Median	19.805	12.07	6.455	4.98	1.99
Mode	#N/A	#N/A	#N/A	5.91	1.85
Standard Deviation	12.10584	7.190727	2.7672	2.282741	0.7004
Sample Variance	146.5514	51.70655	7.657396	5.210908	0.490561
Kurtosis	-1.04743	-1.23384	-0.78381	-1.30404	2.121665
Skewness	-0.02847	-0.12469	-0.76328	-0.58771	-1.84672
Range	38.49	22.14	8.04	6.25	2.18
Minimum	0.96	0.12	0.02	0.05	0
Maximum	39.45	22.26	8.06	6.3	2.18
Sum	399.53	233.3	109.36	80.07	33.97
Count	20	20	20	20	20
Confidence Level (95.0%)	5.665708	3.365364	1.295089	1.068356	0.327797

Table 12: Descriptive statistics of the data given in table 11.

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
Group 1	20	399.53	19.9765	146.5514
Group 2	20	233.3	11.665	51.70655
Group 3	20	109.36	5.468	7.657396
Group 4	20	80.07	4.0035	5.210908
Group 5	20	33.97	1.6985	0.490561

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	4347.596	4	1086.899	25.68083	1.94E-14	2.467494
Within Groups	4020.719	95	42.32336			
Total	8368.315	99				

Table 13: ANOVA test applied on results given at table 11.

It could be tested if there is a significant statistical difference present between the means of groups by applying ANOVA test. Null hypothesis and alternative hypothesis for the test is given below. Discussion of the valid hypothesis is in the Conclusion and Evaluation section.

H₁: Different concentrations of zinc solutions will affect the growth rate of *Cicer arietinum* L. (Chickpea)

H₀: Different concentrations of zinc solutions wouldn't have any affect on the growth rate of *Cicer arietinum* L. (Chickpea)

Conclusion and Evaluation

My aim in this experiment was to find the effect of adding varying zinc concentrations to the growth rate of *Cicer arietinum* L. (Chickpea).

5 groups were present in this experiment, groups being watered every 2 days with 10 mL water containing 0, 0.25, 0.50, 0.75 and 1.00 grams of zinc for groups 1, 2, 3, 4 and 5 respectively. Watering was done at 20:30. Plant growth was measured by stem length of the plants in terms of centimeters. Measurements were taken daily for 20 days. *Cicer arietinum* L. (Chickpea) plant was used and the source of zinc was zinc sulfate.

The average growth heights of plants were found 19.9765, 11.665, 5.468, 4.0035 and 1.6985 cm for groups 1, 2, 3, 4 and 5 respectively. See graph 1 to observe the behavior of the data. There is a notable decline in the growth rates of the plants as zinc quantities increase.

See table 13, ANOVA test is applied to correctly evaluate this data. ANOVA test results indicate that there is a statistically significant mean difference between groups. This evaluation is made by looking at the P-value. Look at table 13, P-value is indicated by bold. The P-value found is a smaller value than α value.

$$\alpha = 0.05 < \mathbf{P\text{-value} = 1.94 \times 10^{-14}}$$

P-value being smaller than 0.05 indicates that there is a statistically significant mean difference amongst groups. As a result, H_1 : “Different concentrations of zinc solutions will affect the growth rate of *Cicer arietinum* L. (Chickpea)” is accepted and H_0 : “Different concentrations of zinc solutions wouldn’t have any affect on the growth rate of *Cicer arietinum* L. (Chickpea)” is rejected.

Although results seem accurate there are several reasons for possible errors that should be noted. Plants do photosynthesis and produce their own organic material for growth. Therefore the rate of photosynthesis is closely related with the rate of plant growth. As a result, factors affecting photosynthesis reaction rate also affect the growth rate.

The approach angle of the sunlight could change the energy that is absorbed by a body of mass. More light means more heat and energy. Both factors affect the photosynthesis rate. For example sunlight approaching an area in right angle transfers more energy than light coming from 30 degrees. Sunlight may not approach all the plants used in experiment at same angles. Light rays are reflected from lots of surfaces and also could be received by samples from different angles. So the energy that they receive may not be equal therefore changing the photosynthesis rate and growth rate.

Genetic variance is also a major source of error since genes and environmental conditions determine the number of leaves, structure of leaves, sizes of the leaves, structure and length of the plant, photosynthesis rate, hormone production and their management. All these factors affect the photosynthesis rate which is closely related with the stem length of the plant.

The surrounding air and air current in the room are also effective factors against photosynthesis rate. The samples were put next to each other but the air homogeneity could have changed due to environment.

Another source of error could be interference of any microorganism or chemical substance that is carried by the air or soil. Although soil from the same package was used in all plants, it is always possible for microorganisms to produce in any of the plant pots. These organisms or chemicals could have interfered with the process of growth and may affect the results.

Some possible improvements could be made to eliminate errors such as repeating the experiment with soil that has different chemical properties other than Güpaş houseplant soil. Güpaş houseplant soil was used in this experiment, but using natural soil may cause different results. Houseplant soil does not completely demonstrate the natural circumstances for plants. Also using larger pots and doing the experiment outdoors, in the natural environment of *Cicer arietinum* L. (Chickpea) may help demonstrate the natural conditions better.

Increasing the number of trials and test subjects would aid in generalizing the results. The experiment done on large numbers of plants would reflect the agricultural effects of zinc deposition better. With these improvements included, it may be possible to obtain more precise and accurate data.

To conclude that; results, graph and the ANOVA test shows a decline in growth as zinc concentration increases. It is important observation to note is that plants watered with high zinc concentrations dried and turned yellow. The research question was “How is the growth (irreversible change in size) of *Cicer arietinum* L. (Chickpea) in terms of height (cm) effected by different concentrations of Zn^{2+} solutions added to different groups while the soil quality, pH, temperature and pressure is tried to be constant for all groups?” for this experiment. Since it is possible to observe the decline in growth it can be said that increasing amounts of zinc show toxicity and inhibit growth. It is important to note that the results and ANOVA test supports the main hypothesis. So therefore the main hypothesis, H_1 : “Different concentrations of zinc solutions will affect the growth rate of *Cicer arietinum* L. (Chickpea)” is accepted. H_0 : “Different concentrations of zinc solutions wouldn’t have any affect on the growth rate of *Cicer arietinum* L. (Chickpea)” is rejected.

If the results were interpreted in a broad point of view, it is possible to say that high amounts of zinc deposition may reduce the number healthy crops and reduce the yield. These substances deposited inside plants are carried to our bodies by the food we eat, so pollution could affect human health. Reduced yield of crops would have a negative effect on agriculture and economy.

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