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# LEAD NITRATE (Pb $(NO_3)_2$) IMPACT ON SEED GERMINATION AND SEEDLING GROWTH OF DIFFERENT SOYBEAN (*GLYCINE MAX* L.) VARIETIES

**ALI RAHMI KAYA[1] AND TAMER ERYİĞİT[2*]**

[1]*Department of Field Crops, Agricultural Faculty, Kahramanmaras Sutcu Imam University, Kahramanmaraş-Turkey*
[2]*Department of Plant and Animal Production, Gevas Vocational School, Van Yuzuncu Yil University, Van-Turkey*
[*]*Corresponding author's email: tamyigit@hotmail.com*

**Abstract**

The aim of the study was to determine the effects of increasing doses (control, 100, 200, and 400 mg $L^{-1}$) of lead nitrate $(Pb(NO_3))_2$ on seed germination and seedling development of 12 different soybean varieties in the Department of Field Crops laboratory, Faculty of Agriculture, Kahramanmaras Sutcu İmam University in May 2017. It was carried out according to the Completely randomized block design with three replications. In the experiment, some basic germination and seedling growth determining parameters such as germination percentage, germination index, radicle length, plumule length, seedling length, radicle fresh weight, plumule fresh weight, seedling fresh weight, radicle dry weight, plumule dry weight, seedling dry weight, vigor index, and germinated seed number were observed. Based on the characteristics studied in the trial, it was observed that cultivars reacted differently to lead concentrations due to their genotypic structure. Therefore, not only Pb doses were found to have negative effects on some characteristics of varieties, but also, they were also found to have positive effects on some properties of the varieties. These different responses to lead, a heavy metal, show that some kinds of soybeans can be used to resist said heavy metal doses.

**Key words:** Germination, Lead nitrate $(Pb(NO_3))_2$, Seed, soybean (*Glycine max* L.), Vigor index.

## Introduction

Plants absorb many minerals from the soil, some of which are known to have no biological function and some to be toxic at low concentrations. As plants form the basis of the food chain, some fears have been increased about the possibility of toxic amounts of certain minerals being transported from plants to higher layers of the food chain. Therefore, special attention has been paid to the mechanisms of absorption and biotransformation in plants, as well as its role in bio-deposition and its influence on consumers, especially humans (Peralta-Videa *et al.*, 2009). Heavy metal contamination has devastating effects on plant productivity and threatens human and animal health (Lamhamdi *et al.*, 2011). Plants are in the target of a wide extent of pollutants that have different concentrations, types and toxic effects. The plant system is exposed to such pollutants mainly in the soil (Arshad *et al.*, 2008) or atmosphere (Pourrut *et al.*, 2011; Uzu *et al.*, 2010). Lead is one of the most toxic and frequently faced heavy metals among known pollutants that influence plants (Grover *et al.*, 2010; Pourrut *et al.*, 2011; Shahid *et al.*, 2011).

Lead (Pb) is one of the most widely and regularly released heavy metals found in various forms in natural resources all over the world (Divya *et al.*, 2015; LeBrón *et al.*, 2019; Lone *et al.*, 2006; Nriagu, 1992). Lead carries on to be widely used in many industries and their processes at increasing rates and occurs as a major pollutant in all environments (atmosphere, soils, water, and living organisms) (Hussain *et al.*, 2006; Islam *et al.*, 2008). Many factors such as exhaust gases of motor vehicles, mines, metal working plants, industrial activities, lead-contaminated waste water, industrial waste, and fertilization in agriculture are the main reasons for lead contamination of soil and plants (Kıran & Şahin, 2005; Nascimento & Marques, 2018).

Lead is known to cause a wide range of toxic impacts on morphological physiologically and biochemically in the origin of the living organism that disrupts seed germination, seedling development, root elongation, plant growth, the function of the chloroplast, chlorophyll production, transpiration, and cell division (Pourrut *et al.*, 2011; Sharma & Dubey, 2005). However, the range of these effects varies depending on the concentration of lead tested, the duration of exposure, the stage of plant development, the intensity of plant stress, and the specific organs studied. Several methods are being developed by plants to respond to toxic metal exposures. The plants have internal detoxification mechanisms to prevent metal toxicity that includes selective mineral uptake discharge by particular ligands, and compartmentalization (Jiang & Liu, 2010; Pourrut *et al.*, 2011).

Legumes are viewed as more suitable to grow in polluted soils than Chenopodiaceae, Compositae, Liliaceae, and Umbelliferae because they absorb the least amounts of lead (Pourrut *et al.,* 2011). Soybean is a Legumes recognized as a "Wonderful Plant" in the world because of the valuable nutrients they contain and the commercial value of their products. Its seeds have an average of 40% high-quality protein and 20 % fat (Imtiyaz *et al.*, 2014), which contains a high amount of the polyunsaturated essential oils acids such as linoleic (18:2) and linolenic (18:3) acids (Söğüt & Öztürk, 2018). It is preferred by extended varieties of climates and soils and thus, it is considered to be the most economical crop. Soybean protein is rich in valuable amino acids (5%) in which most of the cereals are deficient (Imtiyaz *et al.*, 2014). In view of the information presented above, an investigation was carried out to determine the toxic effects of lead on the germination and seedling growth parameters of *Glycine max* L.

## Material and Methods

The research was conducted in a laboratory under the uniform condition at 25°C (±2) in the Department of Field Crops, Faculty of Agriculture, Kahramanmaras Sutcu Imam University in 2016. Healthy and uniform size seeds of 10 soybean (*Glycine max* L.) cultivars used in this study were rinsed with tap water after sterilized with 5% NaOCl (sodium hypochlorite) solution for 5 minutes. In the study, lead nitrate Pb $(NO_3)_2$) as a stress factor was prepared at four concentration levels of 0, 100, 200, and 400 mg $L^{-1}$ respectively. The study was carried out according to the Completely Randomized Experimental Design (CRD) with three replications. In the experiment, 25 seeds of each cultivar were placed to germinate for 14 days in 144 sterile petri dishes, each of which had two filter papers placed. After then, 15 ml from all prepared concentrations were added to each petri dishes during sowing. Then, 10 ml of these solutions were added seven times two days apart for each treatment. After germination, when the cotyledons were fully emerged (after 14 days), germinated seeds were taken out from the petri dishes, and some basic germination and seedling growth parameters such as germination percentage, germination index, radicle length, plumule length, seedling length, radicle fresh weight, plumule fresh weight, seedling fresh weight, radicle dry weight, plumule dry weight, seedling dry weight, vigor index, and germinated seed number were determined. Germination percentage was determined after dividing the number of germinated seeds by the number of seeds, multiplied by 100. The seedling length was measured with a ruler. Similarly, the length of the radicle and plumula were determined by measuring with a measuring band after both separated. Then, these two pieces were weighed to determine fresh weight. Samples of these two plant parts were kept at 78°C for 24 hours and then weighed to achieve seedling dry weight. The seedling vigor index was obtained by multiplying the seedling length by the percentage of germination.

**Statistical analysis of data:** In the study, each treatment was repeated three times. The statistical analysis for the observed treatment factors, cultivars, and lead nitrate concentrations, were performed using one-way analysis of variance (ANOVA) with the Completely Randomized Experimental Design procedures by SAS statistical software. The least Significant Difference (LSD) analysis was performed from Post hoc multiple comparison tests to determine the difference between the levels of Pb-stress in each studied parameter at (%5 significance level. Additionally, the Pearson Correlation analysis was performed to monitor the relationship among the observed parameters.

## Results

As shown in Tables 1 and 2, the varieties, lead doses, and interactions in all the parameters studied showed statistically significant (%1) differences within themselves.

**Germination percentage:** When the averages of germination rates from Table 1 are examined, it is observed that there is very significant statistical (1%) variation among the varieties. The highest germination rate was seen in Cinsoy cultivars with 90.00%, while the lowest germination rates were seen in Arısoy (69.33%) and Nova (71.00%) cultivars (Table 1). In terms of its effect on germination rates, there were statistically significant (1%) variations among lead doses. The highest germination rate (85.33%) was obtained with 100 mg $Pb(NO_3)_2$ $L^{-1}$ dose, while the lowest germination rate (75.00%) was obtained with 200 mg $Pb(NO_3)_2$ $L^{-1}$ dose (Table 1). The common effect of cultivar and lead doses on germination rates was found to be statistically (1%) very significant. The highest germination rate (97.33%) was observed in the application of 100 mg lead dose to Cinsoy variety, while the lowest (54.67%) was obtained from the application of 200 mg lead dose to Arısoy variety (Table 1 and Fig. 1/A).

**Germination index:** As seen in Table 1, it was determined that there were statistically very significant (1%) variations among the varieties in terms of germination indices. The highest germination index (7.44) was determined in the Cinsoy cultivar, while the lowest (4.93) was calculated in Arısoy cultivars. In terms of its effect on germination indices, there were statistically very significant (1%) variations among the lead doses. The highest germination index (6.52) was seen at the dose of 400 mg Pb $(NO_3)_2$ $L^{-1}$, while the lowest (5.51) was seen at the dose of 200 mg $Pb(NO_3)_2$ $L^{-1}$ (Table 1). Variety x lead dose interaction was found to have statistically significant (1%) different effects on germination indexes. The highest germination indices (8.28, 8.11) were observed in Cinsoy cultivar x Control and Cinsoy cultivar x 400 mg Pb $(NO_3)_2$ $L^{-1}$ while the lowest germination index (3.68) was found in Arısoy cultivar x 200 mg (Table 1 Fig. 1/B). As shown in Table 1, lead has had different effects on seed germination indices of soybean varieties. Soybean cultivars reacted differently to lead doses due to genotypic differences, which led to significant variation in variety x lead dose interactions.

**Radicle length:** As a result of the variance analysis of the averages of radicle lengths, it was observed that there was a significant statistical variation (1%) among the varieties. It was determined that the highest radicle length was 7.12 cm in the Arısoy cultivar, while the lowest radicle length was 4.78 cm in the Atakişi cultivar. Statistically (1%) significant variation was found among the lead doses in terms of its effect on radicle lengths. The highest radicle length was seen at the control dose with 7.30 cm, while the lowest radicle length was seen at the 200 mg $Pb(NO_3)_2$ $L^{-1}$ dose with 4.78 cm (Table 1).

The effect of variety x lead dose interaction on the length of the radicle was statistically significant (1%). The highest radicle length (8.99 cm) was observed in Türksoy x Control dose, while the lowest (3.34 cm) was observed in the Çetinbey x 200 mg $Pb(NO_3)_2$ $L^{-1}$ dose (Table 1 and Fig. 1/C). Soybean varieties have been found to react differently to lead levels due to their different genotypic structures, and therefore, lead has had different effects on the varieties ' radicle lengths.

**Table 1. The means of GP, GI, RL, PL, SL, RFW, PFW properties of *Glycine max* L. varieties.**

| Varieties | Doses | GP (%) | *;** | GI | *;** | RL (cm) | *;** | PL (cm) | *;** | SL (cm) | *;** | RFW (g) | *;** | PFW (g) | *;** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Atakişi | Control | 81.33 | d-f | 6.82 | cd | 5.93 | f-j | 18.85 | c-e | 24.78 | g-i | 1.123 | m-p | 8.10 | h-l |
| | 100 | 80.00 | e-g | 6.33 | d-g | 4.58 | m-o | 16.58 | e-g | 21.17 | jk | 1.000 | o-q | 8.24 | g-l |
| | 200 | 69.33 | i-k | 5.46 | h-k | 3.48 | pq | 12.02 | hi | 15.50 | no | 0.753 | r-t | 6.24 | n |
| | 400 | 78.67 | e-h | 6.65 | c-e | 5.13 | j-n | 17.83 | d-f | 22.97 | h-j | 1.507 | g-j | 8.40 | g-k |
| | **Mean** | **77.33** | **E** | **6.32** | **C** | **4.78** | **F** | **16.32** | **F** | **21.11** | **E** | **1.096** | **H** | **7.75** | **I** |
| SA 88 | Control | 77.33 | f-h | 5.95 | f-h | 7.22 | de | 22.03 | ab | 29.24 | ab | 1.492 | h-j | 10.27 | c-e |
| | 100 | 80.00 | e-g | 5.96 | f-h | 5.38 | j-l | 16.58 | e-g | 21.97 | jk | 1.330 | jm | 8.72 | g-i |
| | 200 | 85.33 | de | 6.66 | cd | 5.47 | i-k | 20.02 | b-d | 25.50 | gh | 1.053 | op | 8.27 | g-k |
| | 400 | 77.33 | f-h | 6.38 | d-f | 6.30 | fg | 22.88 | a | 29.18 | a-c | 1.257 | k-m | 9.88 | c-f |
| | **Mean** | **80.00** | **E** | **6.24** | **C-E** | **6.09** | **C** | **20.38** | **A** | **26.47** | **A** | **1.283** | **E-G** | **9.29** | **B-D** |
| Cinsoy | Control | 93.33 | ab | 8.28 | a | 6.47 | f | 20.40 | bc | 26.87 | d-g | 1.840 | de | 9.74 | c-f |
| | 100 | 97.33 | a | 7.91 | ab | 6.10 | f-h | 19.00 | cd | 25.10 | gh | 1.587 | g-i | 9.98 | c-f |
| | 200 | 76.00 | f-i | 5.49 | h-j | 4.43 | no | 18.28 | de | 22.72 | h-k | 1.087 | n-p | 8.36 | g-k |
| | 400 | 93.33 | ab | 8.11 | a | 5.50 | i-k | 20.85 | bc | 26.35 | e-g | 1.460 | ij | 10.32 | cd |
| | **Mean** | **90.00** | **A** | **7.45** | **A** | **5.63** | **D** | **19.63** | **A-C** | **25.26** | **BC** | **1.494** | **C** | **9.60** | **HI** |
| May 5312 | Control | 90.67 | bc | 7.59 | b | 7.58 | cd | 20.15 | bc | 27.73 | b-e | 1.233 | lm | 7.93 | i-l |
| | 100 | 82.67 | de | 6.30 | d-g | 5.36 | j-l | 18.17 | de | 23.53 | h-j | 1.503 | h-j | 7.46 | k-m |
| | 200 | 82.67 | de | 5.94 | f-h | 5.75 | g-j | 18.65 | de | 24.40 | hi | 1.210 | mn | 7.80 | j-l |
| | 400 | 88.00 | cd | 7.14 | c | 5.70 | h-j | 22.45 | a | 28.15 | a-d | 1.300 | k-m | 9.23 | f-h |
| | **Mean** | **86.00** | **BC** | **6.74** | **B** | **6.10** | **C** | **19.86** | **AB** | **25.95** | **AB** | **1.312** | **EF** | **8.11** | **EF** |
| Türksoy | Control | 84.00 | de | 6.43 | de | 8.99 | a | 20.68 | bc | 29.67 | a | 1.820 | e | 8.44 | g-j |
| | 100 | 85.33 | de | 6.44 | de | 6.02 | f-h | 17.90 | de | 23.92 | hi | 1.780 | e | 9.35 | fg |
| | 200 | 73.33 | hi | 5.74 | h | 5.40 | jk | 15.30 | g | 20.70 | kl | 1.650 | fg | 7.75 | kl |
| | 400 | 76.00 | f-i | 6.44 | de | 6.18 | fg | 16.85 | ef | 23.03 | h-j | 1.760 | e | 8.70 | g-i |
| | **Mean** | **79.67** | **E** | **6.26** | **CD** | **6.65** | **B** | **17.68** | **E** | **24.33** | **C** | **1.753** | **A** | **8.56** | **FG** |
| Nova | Control | 58.67 | l | 4.62 | l | 7.70 | cd | 19.98 | cd | 27.68 | b-e | 1.240 | lm | 8.57 | g-i |
| | 100 | 74.67 | g-i | 5.71 | h | 5.78 | g-j | 15.28 | g | 21.06 | j-l | 0.960 | pq | 8.75 | gh |
| | 200 | 68.00 | k | 4.97 | k | 5.14 | j-m | 15.84 | fg | 20.98 | kl | 1.040 | op | 7.53 | kl |
| | 400 | 82.67 | de | 6.56 | de | 5.25 | j-m | 17.40 | ef | 22.65 | i-k | 1.177 | m-o | 8.52 | g-i |
| | **Mean** | **71.00** | **G** | **5.47** | **F** | **5.97** | **C** | **17.13** | **EF** | **23.09** | **D** | **1.104** | **H** | **8.34** | **GH** |
| Bravo | Control | 81.33 | ef | 6.42 | de | 7.07 | e | 19.08 | cd | 26.15 | g | 1.340 | j-l | 8.91 | gh |
| | 100 | 92.00 | b | 7.09 | c | 5.48 | i-k | 16.75 | ef | 22.23 | i-k | 1.333 | j-l | 7.54 | kl |
| | 200 | 77.33 | f-h | 6.01 | f-h | 4.22 | o | 17.93 | de | 22.15 | jk | 0.810 | rs | 8.17 | h-l |
| | 400 | 85.33 | de | 7.00 | c | 5.50 | i-k | 16.90 | ef | 22.40 | i-k | 1.500 | h-j | 8.75 | gh |
| | **Mean** | **84.00** | **CD** | **6.63** | **B** | **5.57** | **D** | **17.67** | **E** | **23.23** | **D** | **1.246** | **FG** | **8.34** | **GH** |

**Table 1. (Cont'd.).**

| Varieties | Doses | GP % | *;** | GI | *;** | RL (cm) | *;** | PL (cm) | *;** | SL (cm) | *;** | RFW (g) | *;** | PFW (g) | *;** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Umut** | Control | 80.00 | e-g | 6.37 | d-f | 7.67 | cd | 20.07 | bc | 27.73 | b-e | 1.830 | e | 9.82 | c-f |
| | 100 | 92.00 | b | 6.13 | e-g | 8.07 | b | 20.44 | bc | 28.51 | a-c | 1.603 | gh | 9.85 | c-f |
| | 200 | 69.33 | jk | 4.61 | l | 3.85 | p | 12.92 | h | 16.77 | m | 0.717 | t | 6.93 | mn |
| | 400 | 78.67 | f-h | 5.48 | h-j | 6.28 | fg | 20.68 | bc | 26.96 | d-g | 1.540 | g-i | 9.90 | c-f |
| | **Mean** | **80.00** | **E** | **5.65** | **F** | **6.47** | **B** | **18.53** | **D** | **24.99** | **C** | **1.423** | **D** | **9.13** | **C-E** |
| **Ataem** | Control | 81.33 | ef | 6.13 | e-g | 5.95 | f-i | 20.33 | bc | 26.29 | fg | 1.983 | bc | 10.38 | c |
| | 100 | 82.67 | de | 5.54 | hi | 4.77 | mn | 18.78 | de | 23.54 | h-j | 1.360 | jk | 9.74 | df |
| | 200 | 88.00 | cd | 6.29 | d-g | 5.24 | j-m | 16.34 | fg | 21.58 | jk | 0.963 | pq | 8.62 | g-i |
| | 400 | 78.67 | f-h | 6.35 | d-f | 5.65 | ij | 20.87 | bc | 26.52 | e-g | 1.043 | op | 10.18 | c-e |
| | **Mean** | **82.67** | **D** | **6.08** | **DE** | **5.40** | **DE** | **19.08** | **B-D** | **24.48** | **C** | **1.347** | **E** | **9.73** | **A** |
| **Arısoy** | Control | 73.33 | hi | 5.11 | k | 7.77 | bc | 19.55 | cd | 27.32 | d-f | 1.417 | j | 8.59 | g-i |
| | 100 | 77.33 | f-h | 5.19 | jk | 5.82 | g-j | 20.38 | bc | 26.20 | g | 1.997 | b | 9.02 | gh |
| | 200 | 54.67 | m | 3.68 | m | 7.30 | de | 19.42 | cd | 26.72 | e-g | 1.250 | lm | 8.77 | gh |
| | 400 | 72.00 | ij | 5.72 | h | 7.60 | cd | 16.47 | fg | 24.07 | hi | 1.310 | k-m | 8.74 | gh |
| | **Mean** | **69.33** | **G** | **4.93** | **G** | **7.12** | **A** | **18.96** | **CD** | **26.08** | **AB** | **1.494** | **C** | **8.78** | **EF** |
| **Çetinbey** | Control | 81.33 | ef | 5.83 | gh | 7.73 | c | 18.07 | de | 25.80 | g | 1.810 | e | 10.37 | c |
| | 100 | 86.67 | d | 6.24 | e-g | 5.12 | k-n | 14.95 | g | 20.07 | kl | 2.233 | a | 11.76 | a |
| | 200 | 80.00 | e-g | 5.88 | gh | 3.34 | q | 10.59 | i-k | 13.93 | o | 0.753 | st | 4.76 | o |
| | 400 | 88.00 | cd | 6.24 | e-g | 4.90 | l-n | 13.35 | h | 18.25 | l | 1.730 | e-g | 11.14 | b |
| | **Mean** | **84.00** | **CD** | **6.05** | **E** | **5.27** | **E** | **14.24** | **G** | **19.51** | **F** | **1.632** | **B** | **9.51** | **A-C** |
| **May 5414** | Control | 90.67 | bc | 6.93 | c | 7.55 | cd | 19.90 | cd | 27.45 | c-e | 0.863 | qr | 9.59 | ef |
| | 100 | 93.33 | b | 6.09 | fg | 5.52 | ij | 16.67 | ef | 22.18 | jk | 1.377 | jk | 9.34 | fg |
| | 200 | 76.00 | f-i | 5.35 | i-k | 3.70 | p | 12.65 | h | 16.35 | jk | 0.737 | st | 7.26 | l-n |
| | 400 | 86.67 | d | 6.16 | e-g | 5.12 | k-n | 16.10 | fg | 21.22 | n | 1.913 | cd | 9.67 | d-f |
| | **Mean** | **86.67** | **B** | **6.13** | **C-E** | **5.47** | **DE** | **16.33** | **F** | **21.80** | **E** | **1.223** | **G** | **8.97** | **D-F** |
| **Means of lead doses*** ** | Control | **81.11** | *B* | **6.37** | *AB* | **7.30** | *A* | **19.92** | *A* | **27.23** | *A* | **1.499** | *A* | **9.23** | *AB* |
| | 100 | **85.33** | *A* | **6.24** | *B* | **5.67** | *B* | **17.62** | *C* | **23.29** | *C* | **1.505** | *A* | **9.15** | *B* |
| | 200 | **75.00** | *C* | **5.51** | *C* | **4.78** | *C* | **15.83** | *D* | **20.61** | *D* | **1.002** | *C* | **7.54** | *C* |
| | 400 | **82.11** | *AB* | **6.52** | *A* | **5.76** | *B* | **18.55** | *B* | **24.31** | *B* | **1.458** | *B* | **9.45** | *A* |
| **LSD** of V | | **2.460** | | **0.210** | | **0.260** | | **0.830** | | **0.920** | | **0.070** | | **0.420** | |
| **LSD** of LD | | **1.410** | | **0.120** | | **0.150** | | **0.480** | | **0.540** | | **0.040** | | **0.240** | |
| **LSD** of V x LD | | **8.510** | | **0.730** | | **0.920** | | **2.880** | | **3.210** | | **0.244** | | **1.448** | |
| **CV (%)** | | **3.750** | | **4.220** | | **5.550** | | **5.700** | | **4.800** | | **20.550** | | **5.830** | |

**GP:** Germination Percentage, **GI:** Gemination Index, **RL:** Radicle Length, **PL:** Plumule Length, **SL:** Seedling Length, **RFW:** Radicle Fresh Weight, **PFW:** Plumule Fresh Weight, **V:** Varieties, **LD:** Lead doses

***:** The means in the same column, expressed in lowercase and indicated with different letters, are statistically different from each other at level of 5% according to LSD test

****:** The means in the same column, expressed in bold capital and indicated with different letters, are statistically different from each other at level of 5% according to LSD test

*****:** The means in the same column, expressed in *italic capital* and indicated with different letters, are statistically different from each other at level of 5% according to LSD test

**Table 2. The means of SWF, RDW, PDW, SDW, SVI, GSN properties of *Glycine max* L. varieties.**

| Varieties | Doses | SFW (g) | *;** | RDW (g) | *;** | PDW (g) | *;** | SDW (g) | *;** | SVI | *;** | GSN (pieces) | *;** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Atakişi | Control | 9.227 | i-l | 0.130 | h-l | 0.827 | h-m | 0.957 | j-n | 2015.55 | f-i | 20.33 | c-h |
| | 100 | 9.243 | i-l | 0.117 | j-l | 0.867 | g-l | 1.643 | ab | 1692.03 | lm | 20.00 | d-h |
| | 200 | 6.993 | m | 0.107 | kl | 0.817 | i-m | 0.923 | k-n | 1073.67 | r | 17.33 | h-j |
| | 400 | 9.903 | g-k | 0.127 | i-l | 0.813 | j-m | 0.940 | k-n | 1812.40 | kl | 19.67 | e-i |
| | **Mean** | **8.842** | **D** | **0.120** | **H** | **0.831** | **D-F** | **1.116** | **CD** | **1648.41** | **G** | **19.33** | **F** |
| SA 88 | Control | 11.765 | c-f | 0.140 | g-k | 0.947 | e-j | 1.087 | g-k | 2262.08 | c | 19.33 | f-i |
| | 100 | 10.053 | g-j | 0.137 | h-k | 0.863 | h-l | 1.000 | j-m | 1756.18 | l | 20.00 | e-h |
| | 200 | 9.327 | i-l | 0.127 | j-l | 0.830 | h-l | 0.957 | k-n | 2176.40 | cd | 21.33 | b-f |
| | 400 | 11.137 | e-g | 0.150 | f-j | 0.917 | f-k | 1.067 | h-k | 2256.13 | c | 19.33 | f-i |
| | **Mean** | **10.571** | **B** | **0.139** | **FG** | **0.889** | **CD** | **1.028** | **E** | **2112.70** | **CD** | **20.00** | **D-F** |
| Cinsoy | Control | 11.580 | d-f | 0.170 | ef | 0.907 | g-k | 1.077 | h-k | 2509.43 | b | 23.33 | ab |
| | 100 | 11.567 | d-f | 0.163 | e-g | 0.987 | d-h | 1.150 | e-i | 2442.60 | b | 24.33 | a |
| | 200 | 9.450 | i-k | 0.160 | e-h | 0.907 | g-k | 1.067 | h-k | 1726.10 | l | 19.00 | g-i |
| | 400 | 11.780 | c-e | 0.180 | de | 0.947 | f-j | 1.127 | f-j | 2461.23 | b | 23.33 | ab |
| | **Mean** | **11.094** | **A** | **0.168** | **C** | **0.937** | **BC** | **1.110** | **CD** | **2284.84** | **A** | **22.50** | **A** |
| May 5312 | Control | 9.167 | j-l | 0.130 | i-l | 0.743 | lm | 0.873 | mn | 2512.95 | b | 22.67 | a-d |
| | 100 | 8.963 | kl | 0.137 | h-k | 0.770 | lm | 0.907 | mn | 1946.08 | h-j | 20.67 | c-g |
| | 200 | 9.013 | kl | 0.180 | de | 0.780 | lm | 0.960 | j-m | 2017.65 | f-h | 20.67 | c-g |
| | 400 | 10.527 | g | 0.160 | e-h | 0.827 | i-m | 0.987 | j-m | 2477.20 | b | 22.00 | b-e |
| | **Mean** | **9.418** | **C** | **0.152** | **DE** | **0.780** | **F** | **0.932** | **FG** | **2238.47** | **B** | **21.50** | **A-C** |
| Türksoy | Control | 10.260 | g-i | 0.143 | g-j | 0.777 | lm | 0.920 | l-n | 2491.56 | b | 21.00 | c-f |
| | 100 | 11.130 | e-g | 0.153 | f-i | 0.827 | i-m | 0.980 | j-m | 2039.18 | fg | 21.33 | c-f |
| | 200 | 9.397 | i-k | 0.150 | g-j | 0.763 | lm | 0.913 | mn | 1521.18 | o | 18.33 | hi |
| | 400 | 10.463 | gh | 0.157 | f-h | 0.860 | h-l | 1.017 | j-l | 1752.25 | l | 19.00 | g-i |
| | **Mean** | **10.313** | **B** | **0.151** | **DE** | **0.807** | **EF** | **0.958** | **FG** | **1951.04** | **E** | **19.92** | **EF** |
| Nova | Control | 9.810 | h-k | 0.140 | h-k | 0.817 | j-m | 0.957 | k-n | 1622.03 | mn | 14.67 | jk |
| | 100 | 9.713 | i-k | 0.110 | kl | 0.847 | h-l | 0.957 | k-n | 1574.64 | no | 18.67 | hi |
| | 200 | 8.570 | l | 0.123 | j-l | 0.760 | lm | 0.883 | mn | 1425.69 | p | 17.00 | ij |
| | 400 | 9.693 | i-k | 0.140 | h-k | 0.697 | m | 0.837 | n | 1871.60 | k | 20.67 | c-g |
| | **Mean** | **9.447** | **C** | **0.128** | **GH** | **0.780** | **F** | **0.909** | **G** | **1623.49** | **G** | **17.75** | **G** |
| Bravo | Control | 10.247 | g-i | 0.137 | h-k | 0.827 | i-m | 0.963 | j-m | 2129.27 | de | 20.33 | d-h |
| | 100 | 8.877 | kl | 0.137 | h-k | 0.793 | lm | 0.930 | k-n | 2042.60 | fg | 23.00 | a-c |
| | 200 | 8.980 | kl | 0.107 | l | 0.903 | g-k | 1.010 | j-l | 1715.23 | l | 19.33 | f-i |
| | 400 | 10.253 | g-i | 0.153 | f-i | 0.903 | g-k | 1.057 | i-k | 1909.67 | i-k | 21.33 | c-f |
| | **Mean** | **9.589** | **C** | **0.134** | **FG** | **0.857** | **DE** | **0.990** | **EF** | **1949.19** | **E** | **21.00** | **B-D** |

**Table 2. (Cont'd.).**

| Varieties | Doses | SFW (g) | *;** | RDW (g) | *;** | PDW (g) | *;** | SDW (g) | *;** | SVI | *;** | GSN (pieces) | *;** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Umut** | Control | 11.653 | d-f | 0.193 | d | 1.023 | c-f | 1.217 | d-f | 2218.87 | c | 20.33 | d-h |
| | 100 | 11.457 | ef | 0.167 | ef | 0.900 | g-k | 1.067 | i-k | 2622.92 | a | 23.00 | a-c |
| | 200 | 7.650 | m | 0.123 | j-l | 0.953 | e-j | 1.077 | h-k | 1162.57 | r | 17.33 | ij |
| | 400 | 11.443 | ef | 0.163 | e-g | 0.993 | d-g | 1.157 | e-h | 2122.09 | d-f | 19.67 | f-i |
| | **Mean** | **10.551** | **B** | **0.162** | **CD** | **0.967** | **B** | **1.130** | **BC** | **2031.61** | **D** | **20.08** | **D-F** |
| **Ataem** | Control | 12.367 | c | 0.170 | ef | 1.047 | b-e | 1.217 | d-f | 2135.68 | d | 20.33 | d-h |
| | 100 | 11.100 | e-g | 0.143 | g-j | 1.027 | b-f | 1.170 | e-h | 1947.24 | h-j | 20.67 | c-g |
| | 200 | 9.587 | i-k | 0.160 | f-h | 1.003 | d-g | 1.163 | e-h | 1899.33 | jk | 22.00 | b-e |
| | 400 | 11.223 | ef | 0.147 | g-j | 1.073 | b-d | 1.220 | d-f | 2086.63 | ef | 19.67 | f-i |
| | **Mean** | **11.069** | **A** | **0.155** | **DE** | **1.038** | **A** | **1.193** | **AB** | **2017.22** | **D** | **20.67** | **C-E** |
| **Arısoy** | Control | 10.007 | g-j | 0.140 | h-k | 0.813 | k-m | 0.953 | k-n | 2000.82 | g-i | 18.33 | hi |
| | 100 | 11.017 | fg | 0.157 | f-h | 0.683 | m | 0.840 | n | 2026.72 | fg | 19.33 | g-i |
| | 200 | 10.023 | g-j | 0.400 | a | 0.967 | e-i | 1.367 | c | 1458.88 | p | 13.67 | k |
| | 400 | 10.050 | g-j | 0.173 | e | 0.880 | g-k | 1.053 | i-k | 1733.53 | l | 18.00 | hi |
| | **Mean** | **10.274** | **B** | **0.218** | **B** | **0.836** | **D-F** | **1.053** | **DE** | **1804.99** | **F** | **17.33** | **G** |
| **Çetinbey** | Control | 12.180 | cd | 0.240 | b | 1.023 | d-f | 1.263 | d | 2098.30 | d-f | 20.33 | d-h |
| | 100 | 13.997 | a | 0.397 | a | 1.253 | a | 1.650 | a | 1739.90 | l | 21.67 | b-e |
| | 200 | 5.510 | n | 0.217 | c | 0.373 | n | 0.590 | o | 1113.17 | r | 19.67 | f-i |
| | 400 | 12.867 | b | 0.243 | b | 1.250 | a | 1.493 | b | 1607.10 | mn | 22.00 | b-e |
| | **Mean** | **11.139** | **A** | **0.274** | **A** | **0.975** | **B** | **1.249** | **A** | **1639.62** | **G** | **20.92** | **B-E** |
| **May 5414** | Control | 10.457 | gh | 0.133 | h-k | 1.067 | b-d | 1.200 | d-g | 2487.97 | b | 22.67 | b-d |
| | 100 | 10.720 | g | 0.163 | e-g | 1.087 | bc | 1.250 | de | 2067.33 | f | 23.33 | ab |
| | 200 | 7.997 | m | 0.133 | h-k | 0.980 | e-h | 1.113 | g-j | 1243.31 | q | 19.33 | g-i |
| | 400 | 11.583 | d-f | 0.147 | g-j | 1.090 | b | 1.237 | de | 1840.45 | k | 21.67 | b-e |
| | **Mean** | **10.189** | **B** | **0.144** | **EF** | **1.056** | **A** | **1.200** | **A** | **1909.77** | **E** | **21.75** | **AB** |
| **Means of lead doses***** | Control | **10.73** | *AB* | **0.156** | *C* | **0.902** | *B* | **1.057** | *B* | **2207.04** | *A* | **20.30** | *B* |
| | 100 | **10.65** | *B* | **0.165** | *AB* | **0.909** | *B* | **1.129** | *A* | **1991.45** | *C* | **21.33** | *A* |
| | 200 | **8.54** | *C* | **0.166** | *A* | **0.836** | *C* | **1.002** | *C* | **1544.43** | *D* | **18.75** | *C* |
| | 400 | **10.91** | *A* | **0.162** | *B* | **0.938** | *A* | **1.099** | *B* | **1994.19** | *B* | **20.53** | *B* |
| **LSD** of V | | **0.450** | | **0.011** | | **0.060** | | **0.060** | | **42.420** | | **1.020** | |
| **LSD** of LD | | **0.260** | | **0.006** | | **0.030** | | **0.040** | | **24.490** | | **0.590** | |
| **LSD** of V x LD | | **1.544** | | **0.041** | | **0.207** | | **0.223** | | **146.930** | | **3.540** | |
| **CV (%)** | | **5.390** | | **8.390** | | **8.230** | | **7.400** | | **2.710** | | **6.220** | |

**SFW:** Seed Fresh Weight, **RDW:** Radicle Dry Weight, **PDW:** Plumule Dry Weight, **SDW:** Seed Dry Weight, **SVI:** Seed Vigor Index, **GSN:** Germinated Seed Number, **V:** Varieties, **LD:** Lead doses

***:** The means in the same column, expressed with lowercase and indicated with different letters, are statistically different from each other at level of 5% according to LSD test.

****:** The means in the same column, expressed with bold capital and indicated with different letters, are statistically different from each other at level of 5% according to LSD test.

*****:** The means in the same column, expressed with *italic capital* and indicated with different letters, are statistically different from each other at level of 5% according to LSD test.

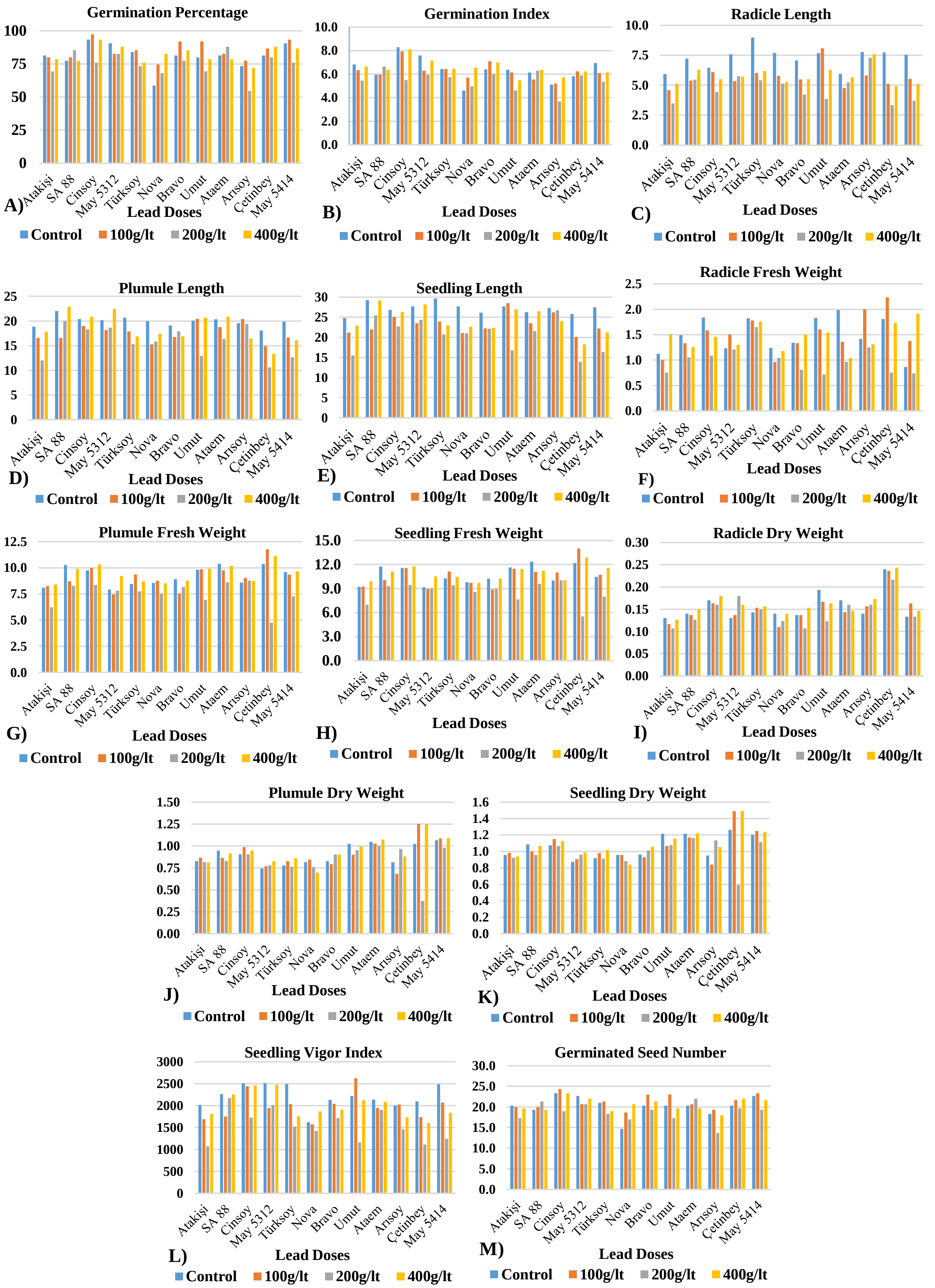


Fig. 1. Effect of lead treatment on the level of Germination percentage (**A**), Germination index (**B**), Radicle length (**C**), Plumule length (**D**), Seedling length (**E**), Radicle fresh weight (**F**), Plumule fresh weight (**G**), Seedling fresh weight (**H**), Radicle dry weight (**I**), Plumule dry weight (**J**), Seedling dry weight (**K**), Seedling vigor index (**L**), Germinated seed number (**M**).

**Table 3. Correlation table for observed parameters of soybean varieties.**

| | GI | RL | PL | SL | RFW | PFW | SFW | RDW | PDW | SDW | SVI | GSN |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GP | 0.808 ** | 0.030 | 0.156 | 0.128 | 0.280 ** | 0.310 ** | 0.326 ** | 0.208 * | 0.171 * | 0.197 * | 0.653 ** | 0.973 ** |
| GI | 1 | 0.079 | 0.271 ** | 0.230 ** | 0.213 * | 0.248 ** | 0.258 ** | 0.072 | 0.046 | 0.056 | 0.634 ** | 0.769 ** |
| RL | | 1 | 0.627 ** | 0.812 ** | 0.401 ** | 0.381 ** | 0.414 ** | 0.121 | 0.048 | 0.067 | 0.629 ** | 0.037 |
| PL | | | 1 | 0.964 ** | 0.304 ** | 0.467 ** | 0.463 ** | -0.064 | 0.089 | 0.070 | 0.821 ** | 0.145 |
| SL | | | | 1 | 0.365 ** | 0.481 ** | 0.488 ** | -0.007 | 0.083 | 0.076 | 0.830 ** | 0.121 |
| RFW | | | | | 1 | 0.621 ** | 0.757 ** | 0.500 ** | 0.280 ** | 0.353 ** | 0.414 ** | 0.272 * |
| PFW | | | | | | 1 | 0.982 ** | 0.425 ** | 0.710 ** | 0.736 ** | 0.519 ** | 0.294 ** |
| SFW | | | | | | | 1 | 0.474 ** | 0.659 ** | 0.698 ** | 0.531 ** | 0.311 ** |
| RDW | | | | | | | | 1 | 0.324 ** | 0.488 ** | 0.084 | 0.185 |
| PDW | | | | | | | | | 1 | 0.984 ** | 0.144 | 0.171 * |
| SDW | | | | | | | | | | 1 | 0.148 | 0.193 * |
| SVI | | | | | | | | | | | 1 | 0.633 ** |

****:** Correlation is significant at the 0.01 level. Pearson Correlation
*** :** Correlation is significant at the 0.05 level.
**GP:** Germination Percentage, **GI:** Gemination Index, **RL:** Radicle Length, **PL:** Plumule Length, **SL:** Seedling Length, **RFW:** Radicula Fresh Weight, **PFW:** Plumule Fresh Weight, **SFW:** Seed Fresh Weight, **RDW:** Radicle Dry Weight, **PDW:** Plumule Dry Weight, **SDW:** Seed Dry Weight, **SVI:** Seed Vigor Index, **GSN:** Germinated Seed Number

In Table 3, it is found that the germination percentage presented significant (%1) positive correlations with germination index (r=0.808), radicle fresh weight (r=0.280), plumula fresh weight (r=0.310), seedling fresh weight (r=0.326), seedling vigor index (r=0.653) and germinated seed number (r=0.973). additionally, it was concluded that radicle dry weight (r=0.208), plumula dry weight (r=0.171) and seedling dry weight (0.197) were correlated positively at 5% significant level.

**Plumule length:** When the averages of plumula lengths are examined in Table 1, it is observed that there is a very significant variation between varieties statistically (1%). The highest plumule length was found to be 20.38 cm from the SA 88 cultivar and 14.24 cm from May 5414 cultivar. There was a statistically significant difference (1%) between lead doses in terms of the effect on plumule lengths. The highest plumule length was seen in the control dose as 19.92 cm, while the lowest was seen in 200 mg $Pb(NO_3)_2$ $L^{-1}$ dose as 15.83 cm (Table 1). Variety x lead dose interaction was found to have statistically significant (1%) different effects on plumule lengths. The highest plumule lengths were observed in SA 88 cultivar x 400 mg $Pb(NO_3)_2$ $L^{-1}$ (22.88 cm) and May 5312 cultivar x 400 mg $Pb(NO_3)_2$ $L^{-1}$ (22.45 cm), while the lowest (10.59 cm) was obtained from Çetinbey cultivar x 200 mg $Pb(NO_3)_2$ $L^{-1}$ treatment (Table 1 and Fig. 1/D).

**Seedling length:** As seen in Table 1, it is seen that there is a statistically significant variation (1%) among the varieties in terms of seedling lengths. The highest seedling length was observed in SA 88 cultivar as 26.47 cm, while the lowest seedling length was observed in Çetinbey cultivar as 19.51 cm (Table 1). When the effect of lead doses on seedling lengths is examined, it is seen that there is a statistically significant variation (1%) among lead doses. The highest seedling length was observed as 27.23 cm from the control dose, while the lowest seedling length was determined as 20.61 cm from the 200 mg $Pb(NO_3)_2$ $L^{-1}$ dose (Table 1). According to the results, it was observed that there were significant (1%) variations in the effect of cultivar x dose interaction on seedling lengths. The highest seedling length (29.67 cm) was determined in Türksoy cultivar x Control dose interaction, and the lowest seedling length (13.93 cm) was observed in Çetinbey cultivar x 200 mg $Pb(NO_3)_2L^{-1}$ application (Table 1 and Fig. 1/E).

**Radicle fresh weight:** When the average fresh weights of the radicals are examined from Table 1, it is seen that there is a significant variation (1%) among the varieties. The maximum radicle fresh weight (1.753 g) was measured in the Türksoy cultivar, while the lowest (1.096 g) was measured in May 5414 cultivar. In Table 1, it is seen that there is a statistically significant (1%) variation among the lead doses in terms of its effect on the radicle fresh weights. The highest radicle fresh weights (1.505, 1.499 g) were seen in 100 mg $Pb(NO_3)_2L^{-1}$ and control doses, while the lowest radical fresh weight (1.002 g) was seen in 200 mg $Pb(NO_3)_2$ $L^{-1}$ treatment (Table 1). In Table 1, it is seen that there is a statistically significant variation (1%) in the effect of varieties x lead dose interactions on radicle fresh weights. The maximum radicle fresh weight (2.233 g) was seen in Çetinbey variety x 200 mg $Pb(NO_3)_2$ $L^{-1}$ treatment, while the lowest radicle fresh weight (0.717 g) was seen in Umut variety x 200 mg dose $Pb(NO_3)_2$ $L^{-1}$ application (Table 1 and Fig. 1/F).

**Plumule fresh weight:** When the averages of plumula fresh weights are examined, it is observed that there are very significant differences among varieties statistically (1%). The highest plumula fresh weight was measured as 9.732g in the Ataem cultivar, while the lowest was 7.75g in the Atakişi cultivar (Table 1). When the results from Table 1 are examined, it is observed that there is statistically significant (1%) variation among lead doses in terms of their effects on Plumula fresh weights. The highest plumula fresh weight (9.45 g) was observed in the dose of 400 mg Pb $(NO_3)_2L^{-1}$, while the lowest (7.54 g) was seen in the 200 mg Pb $(NO_3)_2L^{-1}$ dose (Table 1). As shown in Table 1, it is seen that there are statistically significant (1%) variations in the effect of variety x lead dose interactions on plumule fresh weights. The highest (11.76~~3~~ g) value of plumula fresh weight was observed in Çetinbey cultivar x 100 mg Pb $(NO_3)_2L^{-1}$ dose, while the lowest value was measured as 4.76 g from Çetinbey cultivar x 200 mg Pb $(NO_3)_2L^{-1}$ dose (Table 1 and Fig. 1/G).

**Seedling fresh weight:** When the averages of seedling fresh weights from Table 2 are examined, it is observed that there are statistically very significant (%1) differences among the varieties. The highest seedling fresh weight was observed in Çetinbey, Cinsoy and Ataem (11.138, 11.094 and 11.069, respectively) varieties, while the lowest seedling fresh weight was observed in Atakişi cultivars with 8.84 g. According to the results, there are significant (%1) variations among lead doses in terms of their effects on seedling fresh weights. The highest seedling fresh weight values (10.727 g, 10.910 g, and 10.653 g, respectively) were measured at Control, 400, and 100 Pb $(NO_3)_2L^{-1}$ doses, while the lowest seedling fresh weight (8.541 g) was measured at 200 mg Pb $(NO_3)_2L^{-1}$ dose (Table 2). Variety x dose interaction had statistically significant (1%) effects on seedling fresh weights. The highest seedling fresh weight was measured as 13.997 g from the Çetinbey variety x 100 mg Pb $(NO_3)_2L^{-1}$ application, while the lowest seedling fresh weight (5.510 g) was determined from Çetinbey variety x 200 mg Pb $(NO_3)_2L^{-1}$ treatment (Table 2 and Fig. 1/H).

**Radicle dry weight:** As seen in Table 2, significant differences were found in terms of the dry weight of radicle due to the differences (%1) among the varieties used in the experiment. The highest radicle dry weight was observed in Çetinbey cultivar as 0.234 g, while the lowest radicle dry weight (0.120 g) was observed in the Atakişi cultivar. When the averages of the dry weight of the radicles are examined from Table 2, it is seen that there is a significant variation (1%) among the lead doses. The highest radicle dry weight (0.162 g) was observed at the dose of 400 mg $Pb(NO_3)_2$ $L^{-1}$, while the lowest radicle dry weight was observed at the dose of 200 mg $Pb(NO_3)_2$ $L^{-1}$ as 0.146 g (Table 2). Statistically (1%) there were very significant differences in the effect of variety x lead dose interactions on the dry weight of the radicles. Therefore, the highest radicles dry weights were observed from the treatments of Çetinbey x Control, Çetinbey x 100 mg $Pb(NO_3)_2$ $L^{-1}$ and Çetinbey x 400 mg $Pb(NO_3)_2$ $L^{-1}$ (0.240g, 0.236g and 0.243g, respectively), while the lowest radicles dry weights were observed from applications of Bravo x 200 mg $Pb(NO_3)_2$ $L^{-1}$, Atakişi x 200 mg $Pb(NO_3)_2$ $L^{-1}$ and Nova x 100 mg $Pb(NO_3)_2$ $L^{-1}$ (0.107 g, 0.107 g and 0.110 g, respectively) (Table 1 and Fig. 1/I).

**Plumule dry weight:** When the averages of plumula dry weights are examined from Table 2, it is seen that there are significant variations (1%) among the varieties. Because of the differences among the varieties, high plumula dry weights (1.056 and 1.038 g) obtained from May 5414 and Ataem varieties, while the lowest plumula dry weights were determined from May 5312 and Nova cultivars as 0.780 g. As observed in Table 2, there is a statistically significant variation between lead doses in terms of its effect on plumula dry weights (1%). The highest plumula dry weight was observed at a dose of 400 mg $Pb(NO_3)_2$ $L^{-1}$ as 0.938 g, while the lowest plumula dry weight was observed at a dose of 200 mg $Pb(NO_3)_2$ $L^{-1}$ as 0.836 g (Table 2). Due to the different genotypic structure of the cultivars, they reacted differently to lead doses. Therefore, interactions among the cultivars x lead doses were found to be significant (%1). The highest plumula dry weights (1.253 g and 1.250 g) were observed in Çetinbey variety x 100 mg $Pb(NO_3)_2$ $L^{-1}$ and Çetinbey variety x 400 mg $Pb(NO_3)_2$ $L^{-1}$, while the lowest plumula dry weight was observed in Çetinbey variety x 200 mg $Pb(NO_3)_2$ $L^{-1}$ as 0.373 g (Table 1 and Fig. 1/J).

**Seedling dry weight:** From Table 2, when the seedling dry weights are examined, it is seen that there are significant differences (1%) among the varieties. The highest seedling dry weight was observed in Çetinbey (1.209 g) and May 5414 (1.200 g) varieties, while the lowest seedling dry weight was observed in Nova cultivar as 0.908 g. As a result of the study, it is seen that there is a statistically significant variation (1%) among lead doses in terms of their effects on seedling dry weights. Seedling dry weight ranged from 0.983 g to 1,000 g, while the highest seedling dry weight (1.000 g) was observed at 400 mg $Pb(NO_3)_2$ $L^{-1}$, and the lowest (0.983 g) was at 200 mg $Pb(NO_3)_2$ $L^{-1}$ (Table 2). From the results presented in Table 2, it was seen that there was a significant (1%) variation in the effect of cultivar x dose interaction on seedling dry weights. The highest seedling dry weights were determined from treatments of the Çetinbey variety x 400 mg $Pb(NO_3)_2$ $L^{-1}$ as 1.493 g and Çetinbey variety x 100 mg $Pb(NO_3)_2$ $L^{-1}$ as 1.489 g, while the lowest seedling dry weight (0.590 g) was measured from Çetinbey variety x 200 mg $Pb(NO_3)_2$ $L^{-1}$ application (Table 1 and Fig. 1/K).

**Seedling vigor index:** As seen in Table 2, significant variations were found in terms of seedling vigor index due to the differences (%1) among the varieties used in the experiment. Seedling vigor indices ranged from 1623.49 to 2284.84 in cultivars. The highest seedling vigor index was observed in Cinsoy cultivar as 2284.84, while the lowest seedling vigor index was observed in Nova, Çetinbey and Atakişi (1623.49, 1639.62 and 1648.41) cultivars. According to the results, there were statistically significant differences (1%) among the lead doses in terms of their effects on seedling vigor indices. The highest seedling vigor index was calculated as 2207.04 for the control treatment and the lowest seedling vigor index was calculated 1544.43 for the 200 mg $Pb(NO_3)_2$ $L^{-1}$ dose (Table 2). According to the analysis of data obtained from the study, variety x dose interaction has statistically (1%) significant different effects on seedling vigor indices. So, the highest seedling vigor index was calculated for Umut cultivar x 100 mg $Pb(NO_3)_2$ $L^{-1}$ treatment as 2622.92, while the lowest seedling vigor indices were calculated (1073.67, 1113.17 and 1162.57) for Atakişi, Çetinbey and Umut varieties x 200 mg $Pb(NO_3)_2$ $L^{-1}$ applications (Table 1 and Fig. 1/L).

**Germinated seed number:** When the average number of seeds germinating from Table 2 is examined, it is seen that there is a very significant variation (1%) among the varieties. The highest number of germinating seeds was seen in Cinsoy cultivar as 2.50 pieces, while the lowest number of germinating seeds were observed in Arısoy (17.33 pieces) and Nova (17.75 pieces) cultivars. When the data in Table 2 are examined, it is found that the effects of lead doses on germinating seed number are significant and there is a statistically significant (1%) difference among the doses. According to the doses, the numbers of germinated seeds were varied between 18.75 and 21.33 pieces, and the maximum number of germinated seeds was obtained from 100 mg dose of $Pb(NO_3)_2$ $L^{-1}$ as 21.33 (Table 2). From the results presented in Table 2, it was seen that there were statistically significant (1%) differences in the effects of cultivar x dose interactions on seedling dry weights. The highest number of germinated seeds (24.33 pieces) was observed at the control dose of Cinsoy variety x control treatment, while the lowest number of germinated seeds was observed from Arısoy variety x 200 mg $Pb(NO_3)_2$ $L^{-1}$ application as 13.67 pieces (Table 1 and Fig. 1/M).

**The correlation among the investigated parameters:** A correlation analysis was performed to accurately define the relationships between all investigated properties of soybean. Correlations between most of the parameters studied are thought to be significant (1% and 5%) due to the widespread and complex lead interactions occurring in different plant organs (Table 3). As can be seen from the analysis of correlation values in Table 3, it was observed that there was generally positive interaction among all the properties studied and that there was no negative interaction.

## Discussion

The study is confined to determine the effect of Lead Nitrate on germination percentage, germination index, radicle length, plumule length, seedling length, radicle fresh weight, plumule fresh weight, seedling fresh weight, radicle dry weight, plumule dry weight, seedling dry weight, vigor index and germinated seed number of *Glycine max* L.

In some previous studies, it was reported that lead doses had positive effects on germination parameters in some plants Zaier *et al.*, (2010) and had negative effects on some other plant species (Hussain *et al.*, 2013; Mishra & Choudhuri, 1998; Pourrut *et al.*, 2011; Sethy & Ghosh, 2013). In this study, as a result of the use of 12 different genotypic varieties of soybean, both positive and negative effects were observed on the varieties. As shown in Tables 1, 2 and Figure 1/A-M, lead doses had different and significant effects on all observed parameters in soybean varieties. This is because cultivars have been found to react differently to lead levels due to their genotypic differences. In a few varieties' germination and growth parameters observed were suppressed differentially at all lead treatments. In some varieties, it has been found that many properties are promoted differently in some lead treatments. Similar to the results determined in this study, Islam *et al.*, (2007) reported that at higher concentrations, lead accelerates germination and also causes adverse effects on the length of the radicle and hypocotyl in *Elsholtzia argyi*.

Sethy & Ghosh (2013) and Pourrut *et al.*, (2011) have been reported that lead has strongly affected the seed morphology and physiology, and therefore it inhibits germination. This may be due to the interaction of lead with protease and amylase enzymes that cause germination inhibition (Amin *et al.*, 2018; Sengar *et al.*, 2008). However, as can be seen in this study, this may differ among the plant species. Thus, legumes containing soybeans have been reported to be tolerant to lead levels compared to many other plant species (Alexander *et al.*, 2006; Gupta *et al.*, 2013).

## Conclusions

In the microsphere environment, various ecological and cyclic processes have disrupted due to the toxic effects of heavy metals on the microbial community. One of the most important environmental pollutants is considered as lead. Therefore, in the present study, it was aimed to determine the effect of lead on seed germination and growth parameters of seedlings of 12 soybean (*Glycine max* L.) genotypes. It has been shown that genotypes react differently to increased lead concentrations. It is concluded that significant positive correlations were observed among observed properties of all soybean genotypes under effects of lead concentrations. Moreover, determination of the effects of lead nitrate on seeds germination in 12 soybean varieties will be able to offer preference in the selection of soybean varieties in future studies.

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