© by PSP Volume 28 – No. 9/2019 pages 6574-6579 Fresenius Environmental Bulletin

EFFECTS OF LEAD ON SEED GERMINATION AND SEEDLING GROWTH IN DIFFERENT SESAME (*SESAMUM INDICUM*) GENOTYPES

Ali Rahmi Kaya[1], Tamer Eryigit[2,*], Omer Suha Uslu[1], Osman Gedik[1], Murat Tuncturk[3]

[1]Department of Field Crops, Faculty of Agricultural, Kahramanmaras Sutcu Imam University, Turkey
[2]Department of Plant and Animal Production, Gevas Vocational School, Van Yuzuncu Yil University, Turkey
[3]Department of Field Crops, Faculty of Agricultural, Van Yuzuncu Yil University, Turkey

ABSTRACT

Lead is considered as an essential potent environmental contaminant. Various ecological, environmental and evolutionary processes in the microsphere are disrupted because of lead toxicity to the microbial community. Based on this important perspective, the effects of increasing doses (control, 100, 200 and 400 mg L^{-1}) of Lead Nitrate ($Pb(NO_3)_2$) as heavy metal on seed germination and seedling growth of 11 different sesame genotypes were investigated. The research was carried out according to the Completely Randomized Experimental Design (CRD) with three replications at 25 °C (±2) in the Department of Field Crops laboratory, Faculty of Agriculture, Kahramanmaras Sutcu Imam University in 2016. In the experiment, 25 seeds of each genotype were placed to germinate for 14 days, and then, some basic germination and seedling growth determining parameters such as germination percentage, radicle length, plumula length, seedling length, seedling fresh weight, seedling dry weight and vigor index were observed.

Lead treatments have a strong negative influence on the growth of sesame by reducing significantly all the above parameters. The growth of the plants grown with increasing lead levels were reduced in compared to control plants. As a result, the effects of increasing levels of lead nitrate on the seeds germination percentages of sesame genotypes varied among the genotypes. The most tolerant genotype to the increasing levels of lead nitrate was Muganlı-57. The highest values of the other features examined were found to be obtained from the control applications of the genotypes.

KEYWORDS:
Germination, lead nitrate, seed, sesame (*Sesamum indicum*), vigor index

INTRODUCTION

Heavy metals take roles as fundamental plant micronutrients, however, overabundance concentrations of these substance become poisonous toxins [1]. Beyond acceptable levels, these metals are turned into contaminants in the environment. Additionally, their abundance creates pollution into the atmosphere [2]. They cause toxic effects on animals, plants, and human health [3, 4]. Of these, Cu, Cd, Ni, Zn, Cr, Co and as predominantly Pb, are the most reported metals that are the hazard for the growth and development of plants [4, 5]. The heavy metals that are concentrated in plant tissues are due to the widespread application of phosphate fertilizers, sewage sludge, dust from contaminants, industrial wastes and poor irrigation practices in agricultural land [4, 5]. Among above heavy metals, lead which is considered as one of the major toxic environmental contaminants, has a significant negative effect on the plant metabolic processes [6, 7]. Processes and cycles of various environment, ecology and evolution in the microsphere are deteriorated due to toxic effects of lead on the microbials [8, 9]. Lead has highly toxic effects on living organisms and has no biological function but can cause biochemical, physiological and morphological dysfunctions in all plants [6]. It is not only a toxic element, however can be accumulated in various plant organs and agricultural products [10] and can have toxic effects on animal and human who consumed these sources as food. The main lead content of the soil is derived from the application of tetramethyl lead as a similar antirust agent from the decomposition of geological rock formations, discharge of lead mines, exhausts of automobile, applications in industrial, operations of smelting, impurities of fertilizer, metal coatings and coatings using lead arsenate [11]. However, there is still a problem as far as the exogenous lead can pass through seeds directly from atmospheric pollution or soil solids in contact with the seeds, and consequently can affect germination [12]. In this case, the effect of lead on germination seems likely to depend on the differences in seed structure of different species, particularly the differences in the struc-

ture of seed coats [12]. As is well known, seed coat protects the embryo from harmful external agents [2]. However, the seed layers have a wide variety of anatomical forms not found in any other organ or tissue.

Seed germination is promoted by enzymatic reactions regulation that activate anabolic and catabolic processes in the storage tissues and embryonic axes, respectively, in the first cycle of life in a plant. In this process, germination is prevented even if a single component of the processes is affected. A known understanding of the effect of heavy metals on plant physiology is that it causes a various malnutrition problems, so the storage compounds breakdown is an important event that governs seed germination following water absorption in all plants [13], but the plants show different reactions to these trace elements. However, the effects of heavy metals, especially lead, in this process have not been well documented. To the best of our knowledge, no research has been carried out to monitor the phytotoxic effects of lead on the germination process of different sesame species.

Sesame (*Sesame indicum*) is an important oilseed plant, which is an annual, summery, shrub, from the family Pedaliaceae, planted in semi-arid and arid regions of the world [14] including Turkey. It is important to understand the effects of heavy metal intake, distribution and its potential toxic effects on the germination and growth of sesame seeds.

The purpose of this study is to contribute to the understanding of the effects of lead on seed germination of different sesame genotypes. In this work, the lead uptake by different sesame genotype seedlings, and its impact on germination by analyzing morphological and biochemical properties during the first 14 days of seeds germination was presented.

MATERIALS AND METHODS

The seeds of 11 different sesame (*Sesamum indicum*) genotypes used in the study were sterilized in 5% NaOCl (sodium hypochlorite) solution for 5 minutes. After then, the seeds were rinsed with tap water. Four concentrations levels of Lead Nitrate Pb $(NO_3)_2$) 0, 100, 200 and 400 mg L^{-1} were prepared, respectively. The study was carried out according to the Completely Randomized experimental Design (CRD) with three replications at 25 °C (±2) in the Department of Field Crops laboratory, Faculty of Agriculture, Kahramanmaras Sutcu Imam University in 2016. In the experiment, 25 seeds from each genotype were placed to germinate in 132 sterile petri dishes that two filter papers placed in each. Then, 15 ml from the all prepared concentrations were added to each petri dishes during sowing. After then, 10 ml of these solutions were added seven times two days apart for each treatment. The germinations and seedlings growth were monitored for 14 days. And then, some basic germination and seedling growth determining parameters such as germination percentage, radicle length, plumula length, seedling length, seedling fresh and dry weight and seedling vigor index were investigated. The germination percentage, after dividing the count of germinated seeds by the number of seeds, was determined by multiplying by 100. Seedling length was measured with ruler. Similarly, the length of the radicle and plumula was determined by measuring with a measuring tape after both were separated. Then, these two parts were weighed to determine the fresh weight. The samples of these two plant parts were kept at 78 °C for 24 hours and then weighed to obtain seedling dry weight. The seedling vigor index was obtained by multiplying the seedling length by the percentage of germination.

Statistical analysis. The statistical analysis for the observed treatment factors, genotype and lead nitrate concentrations were performed using anova with the Completely Randomized experimental Design procedures of the Costat v. 6.0. Duncan multiple range test was used to evaluate mean separations. Additionally, the Pearson Correlation analysis was performed to monitor the relationship among the observed parameters with IBM Spss v. 22.0.

RESULTS AND DISCUSSION

Lead is one of the most common heavy metal that does not have biological function but can cause physiological, morphological and biochemical dysfunctions in plants. Because of their genotypic differences, plants develop a broad tolerance mechanism in response to lead exposure [6]. Here, the effects of lead on germination and seedling growth of different sesame genotypes were investigated.

Germination percentage. Lead has been various inhibitory effects on seed germination percentages. It has been determined that different sesame genotypes respond differently to increased lead levels due to genotypic differences. Among the studied sesame genotypes, the most tolerant one, which had the highest germination percentage (99.67%) with no significant variation between concentration levels was Muganlı-57 (Table 1). In a similar study, Islam et al. [15] reported that at higher concentrations, lead may speed up germination of *Elsholtzia argyi*. As shown in Table 1, the lowest germination percentage (80.33%) was found to be Kepsut-99 with the least tolerance to lead nitrate concentrations. This may be due to the interaction of lead with protease and amylase enzymes that

cause germination inhibition [7, 16]. Lead did not show permeability through the seed membrane at the first stage of water absorption. In the second step, germination was delayed because the seed membrane has selective permeability on the lead ions [12]. It can be concluded that the above notification of different explanations and results on germination, are due to changing of the permeability of the membrane from genotype to genotype, even though, it has the same species.

Radicle length. Lead nitrate applications had a significant effect (5%) on decreasing of radicle length in the studied sesame genotypes compared to the controls. The highest radicle lengths were measured in control plots for all genotypes, while the lowest data were observed in plots which treated with fourth concentration levels. For radicle length, the highest tolerant genotype to the increasing lead nitrate levels was Arslanbey variety with 2.02cm radicle length, while the least sensitive one was Kepsut-99 (0.82cm). In a previous study which has a good harmony with this study results, Islam et al. [15] reported that at higher concentrations, lead may meanwhile induce adverse effects on the radical length of *Elsholtzia argyi.*

Plumule length. According to the study results, plumule lengths of sesame genotypes were negatively affected by application of different lead concentration levels. As can be seen in Table 1, increasing of lead nitrate doses decreased the length of plumule simultaneously. The lowest plumule lengths of all genotypes were obtained from fourth doses (400 mg L^{-1}) of lead nitrate treatments, while the longest plumule lengths were obtained from control plots. The variations between the genotypes were found to be statistically significant (5%). The highest plumule length was determined from Hatipoglu variety as 1.97cm. The shortest plumule length (0.74cm) was measured from Kepsut-99 which had least tolerance to lead nitrate doses. It can be said that the different response of the varieties to the lead nitrate doses due to the genotypic structures caused the interaction between the varieties and the lead nitrate doses to be significant. Islam et al. [15] reported that at higher concentrations, lead may simultaneously induce negative effects on the hypocotyl length in *Elsholtzia argyi.*

Seedling length. Seedling length of *Sesamum indicum* genotypes were significantly decreased with phytotoxic metal (lead nitrate) treatments of at 100, 200 and 400 mg L^{-1} as compared to control, and also, a significant variation was detected between genotypes. With increase in concentration levels of lead nitrate, seedling length was decreased. The highest seedling lengths were measured in control plots for all genotypes, while the lowest data were observed in plots which treated with fourth concentration levels. For seedling length, the highest tolerant genotypes to the increasing lead nitrate levels were Arslanbey and Hatipoglu varieties with 3.90 and 3.72 cm seedling lengths, while the least sensitive one was Kepsut-99 (1.55cm). The reduction in seedling length can be said to be due to lead exposure in plants that greatly limits the development and sprouting of seedlings [17]. Similar results were reported for *Thespesia populnea* seedling growth that decreased with lead treatments as compared to control [1]. In another previous study, which had parallel statements with the study results, was declared a steady decline in the seedling growth of *Zea mays* was observed with the increase in lead concentration [4].

Seedling fresh weight. Fresh weight of seedling shows the overall growth of any plant species. And also, the effect of lead on the accumulation of fresh and dry biomass of plant species varies according to plant species, plant varieties, plant organs and metabolic processes [4]. Seedling fresh weight of 11 sesame genotypes were subjected to different concentrations of lead nitrate, and the effects of the concentrations were found to be significant. Therefore, the genotypes and concentration levels created different duncan groups within its self. A negative correlation was observed in fresh weight of seedling with lead nitrate concentrations. The minimum seedling fresh weights of all genotypes were measured from fourth concentration (400 mg L^{-1}), while the maximum seedling fresh weights were obtained from control plots. The highest seedling fresh weight was obtained from Hatipoglu variety as 0.380g, while the lowest seedling fresh weight (0.247g) was measured from Kepsut-99 (Table 1). Similar results were recorded by Hussain et al. [4]. They declared that seedling fresh weight of *Zea mays* was significantly decreased when treated with lead which have a toxic effect on it.

Seedling dry weight. From Table 1 it is seen that genotypes react differently to lead nitrate doses. Therefore, a significant variation was observed between genotypes. Seedling dry weights of all genotypes showed a sharp decrease at 400mg L^{-1} treatment except Köy-2, Arslanbey, Osmanlı-99 and Cumhuriyet-99 compared to controls. The tolerant genotype to lead concentrations was monitored as Cumhuriyet-99 with 0.26g at 400mg L^{-1} treatment. The lowest tolerant genotype was determined as Kepsut-99 which had no observed samples at 400mg L^{-1} treatment. Similar but partially different results were reported by Hussain et al. [4] for *Zea mays*, were treated with different lead concentrations. It can be said that this difference is caused by the difference of plant species.

The seedling vigor index (SVI) was used as a phytotoxicity index to assess the effect of heavy metal on seedling growth [18, 19]. Seedling vigor is a measure of the damage that accumulates along with a decrease in viability, and damage is accumulated in the seeds until the seeds are not germinated and eventually die [19].

TABLE 1
Effects of $Pb(NO_3)_2$ on seed germination, radicle, plumula and seedling length, seedling fresh and dry weight, and seedling vigor index of *Sesamum indicum* L.

Genotypes	Doses (g/lt)	GP	(%)	RL (mm)		PL (mm)		SL (mm)		SFW (g)		SDW (g)		SVI	
Köy-1	Control	100.00	a	4.02	bc	3.53	ab	7.55	bcd	0.421	defg	0.027	cd	755.00	abc
	100	98.67	a	1.04	hij	2.36	de	3.41	hi	0.431	def	0.029	cd	336.07	gh
	200	98.67	a	0.20	klmn	0.75	kl	0.95	lmn	0.238	hijkl	0.027	cd	93.32	klmn
	400	96.00	a	0.10	lmn	0.10	nopqr	0.20	nopq	0.000	o	0.000	d	19.20	nopq
Mean		**98.33**	**AB**	**1.34**	**CD**	**1.68**	**BC**	**3.03**	**B**	**0.272**	**DEF**	**0.021**	**B**	**300.90**	**BC**
Köy-2	Control	98.67	a	4.07	b	3.36	b	7.43	cd	0.464	de	0.070	c	733.55	bc
	100	94.67	a	0.82	ijk	2.16	e	2.97	ij	0.386	efg	0.027	cd	281.37	hi
	200	97.33	a	0.31	klmn	1.03	jk	1.34	l	0.243	ijkl	0.023	cd	129.99	kl
	400	97.33	a	0.10	mn	0.10	nopqr	0.20	nopq	0.137	mn	0.022	cd	19.47	nopq
Mean		**97.00**	**BC**	**1.33**	**CDE**	**1.66**	**C**	**2.99**	**B**	**0.307**	**BCDEF**	**0.036**	**B**	**291.09**	**BC**
Köy-3	Control	98.67	a	4.15	b	2.34	e	6.49	de	0.530	d	1.004	a	640.00	c
	100	98.67	a	1.48	gh	1.71	gh	3.19	i	0.354	fg	0.025	cd	315.55	h
	200	100.00	a	0.42	jklm	0.67	l	1.08	lm	0.241	ijkl	0.027	cd	108.33	klm
	400	94.67	a	0.00	n	0.00	qr	0.00	pq	0.000	o	0.000	d	0.00	pq
Mean		**98.00**	**AB**	**1.51**	**BC**	**1.18**	**E**	**2.69**	**BC**	**0.281**	**CDEF**	**0.264**	**A**	**265.97**	**CD**
Arslanbey	Control	98.67	a	5.42	a	3.37	b	8.79	a	0.516	d	0.029	cd	868.09	a
	100	100.00	a	1.85	fg	2.76	c	4.61	g	0.452	de	0.028	cd	461.07	f
	200	96.00	a	0.58	jkl	1.08	j	1.66	l	0.284	ghij	0.025	cd	159.96	k
	400	96.00	a	0.21	klmn	0.31	mn	0.52	no	0.140	mn	0.025	cd	50.09	no
Mean		**97.67**	**AB**	**2.02**	**A**	**1.88**	**AB**	**3.90**	**A**	**0.348**	**ABC**	**0.027**	**B**	**384.80**	**A**
Hatipoğlu	Control	92.00	a	4.93	b	3.70	a	8.63	ab	0.685	a	0.032	cd	791.60	ab
	100	82.67	c	1.80	g	3.23	b	5.03	f	0.550	cd	0.030	cd	414.17	g
	200	86.67	b	0.18	lmn	0.85	kl	1.02	lm	0.286	ghi	0.027	cd	88.68	lmn
	400	80.00	cd	0.10	mn	0.10	opqr	0.20	opq	0.000	o	0.000	d	16.00	opq
Mean		**85.33**	**F**	**1.75**	**BCD**	**1.97**	**A**	**3.72**	**A**	**0.380**	**A**	**0.022**	**B**	**327.61**	**B**
Tan-99	Control	93.33	a	3.45	c	2.72	cd	6.17	e	0.594	bc	0.030	cd	580.03	d
	100	97.33	a	1.27	h	1.54	hi	2.81	ij	0.470	d	0.030	cd	273.33	hi
	200	78.67	de	0.11	lmn	0.15	nopq	0.26	nopq	0.249	hijk	0.027	cd	20.27	nopq
	400	86.67	b	0.10	mn	0.10	pqr	0.20	opq	0.000	o	0.000	d	17.33	opq
Mean		**89.00**	**E**	**1.23**	**CDE**	**1.13**	**E**	**2.36**	**CD**	**0.328**	**ABCDE**	**0.022**	**B**	**222.74**	**DEF**
Osmangazi-99	Control	100.00	a	2.89	d	2.31	e	5.20	f	0.555	cd	0.031	cd	520.00	e
	100	98.67	a	1.07	hi	1.45	i	2.53	j	0.409	efg	0.027	cd	250.01	i
	200	98.67	a	0.17	lmn	0.24	no	0.40	nop	0.234	kl	0.026	cd	39.83	nop
	400	97.33	a	0.10	mn	0.10	pqr	0.20	opq	0.000	o	0.000	d	19.47	nopq
Mean		**98.67**	**AB**	**1.06**	**DEF**	**1.03**	**EF**	**2.08**	**ED**	**0.299**	**BCDEF**	**0.021**	**B**	**207.33**	**EF**
Osmanli-99	Control	97.33	a	4.04	b	2.60	d	6.64	d	0.606	b	0.028	cd	645.63	c
	100	94.67	a	1.27	h	1.72	g	2.99	i	0.501	d	0.028	cd	282.65	h
	200	94.67	a	0.27	klmn	0.28	n	0.55	n	0.213	l	0.025	cd	51.39	n
	400	80.00	cd	0.14	lmn	0.13	nopq	0.28	nop	0.092	n	0.015	cd	22.13	nopq
Mean		**91.67**	**D**	**1.43**	**BCD**	**1.18**	**DE**	**2.61**	**BCD**	**0.353**	**AB**	**0.024**	**B**	**250.45**	**CDE**
Cumhuriyet-99	Control	96.00	a	2.13	f	1.71	gh	3.84	h	0.353	fg	0.164	b	368.96	g
	100	93.33	a	1.12	hi	1.05	j	2.17	k	0.346	fg	0.027	cd	206.56	j
	200	96.00	a	0.30	klmn	0.43	m	0.73	mn	0.180	lm	0.026	cd	70.85	mn
	400	94.67	a	0.17	lmn	0.20	nop	0.38	nop	0.161	lm	0.026	cd	36.41	nop
Mean		**95.00**	**C**	**0.93**	**EF**	**0.85**	**FG**	**1.78**	**E**	**0.260**	**EF**	**0.061**	**B**	**170.70**	**FG**
Kepsut-99	Control	90.67	a	2.64	e	1.94	f	4.57	g	0.447	de	0.026	cd	416.85	g
	100	92.00	a	0.62	jk	0.91	k	1.54	l	0.300	gh	0.024	cd	142.53	k
	200	77.33	e	0.00	n	0.10	pqr	0.10	pq	0.241	jkl	0.023	cd	7.73	pq
	400	61.33	f	0.00	n	0.00	r	0.00	q	0.000	o	0.000	d	0.00	q
Mean		**80.33**	**G**	**0.82**	**F**	**0.74**	**G**	**1.55**	**E**	**0.247**	**F**	**0.018**	**B**	**141.78**	**G**
Muganli-57	Control	100.00	a	4.87	b	2.76	c	7.63	bc	0.620	b	0.033	cd	763.00	ab
	100	100.00	a	0.93	ij	1.72	g	2.64	ij	0.318	gh	0.029	cd	264.33	hi
	200	98.67	a	0.31	klmn	0.81	kl	1.13	l	0.287	ghi	0.028	cd	111.39	kl
	400	100.00	a	0.12	lmn	0.27	n	0.40	nop	0.105	n	0.002	d	39.67	nop
Mean		**99.67**	**A**	**1.56**	**BC**	**1.39**	**D**	**2.95**	**B**	**0.332**	**ABCD**	**0.023**	**B**	**294.60**	**BC**

GP: Germination percentage**, RL.:** Radicle length**, PL:** Plumula length**, SL:** Seedling length**, SFW:** Seedling fresh weight**, SDW:** Seedling dry weight**, SVI:** Seedling vigor index

*** :** Means with similar letters within each column for each treatment are not significantly different (5%)

TABLE 2
Correlation table for observed parameters of samples

	GR	RL	PL	SL	SFW	SDW	SVI
GR (Germination percentage)	1	0.283**	0.315**	0.306**	0.322**	0.110	0.337**
RL (Radicle length)		1	0.865**	0.976**	0.796**	0.277**	0.977**
PL (Plumula length)			1	0.953**	0.856**	0.189*	0.945**
SL (Seedling length)				1	0.849**	0.249**	0.997**
SFW (Seedling fresh weight)					1	0.198*	0.840**
SDW (Seedling dry weight)						1	0.254**
SVI (Seedling vigor index)							1

**: Correlation is significant at the 0.01 level. Pearson Correlation
* : Correlation is significant at the 0.05 level.

Seedling vigor index. Additionally, vigor index of seedling is an important variable that determines the competitiveness of plant species. The difference between genotypes were found to be significant under various concentrations of lead nitrate as shown in Table 1. A significant sharp and continuous reduction in seed vigor index was observed compared to control, while the lead doses were increased (Table 1). According to the Table 1, the tolerant genotype was determined as Arslanbey, while the lowest tolerant genotype was Kepsut-99.

The relationships among the observed characteristics. A correlation analysis was carried out to demonstrate the effects of lead concentrations on the relationships between all the properties studied. Correlations among all traits examined are thought to be significant (P <1% and P <5%) (Table 2), due to widespread and complex lead interactions occurring in different plant organs.

As can be read from Table 1, germination percentage presented significant (P<0.01) positive correlations with radicle length (r=0.283), plumula length (r=0.315), seedling length (r=0.306), seedling fresh weight (r=0.322) and seedling vigor index (r=0.337). It was found that the radicle length was adversely affected by lead concentrations, so that other investigated properties decreased in parallel with the decrease in radicle length. Therefore, it was found to have positive correlations between radicle length and all other features examined, as plumula length (r=0.865), seedling length (r=0.976), seedling fresh weight (r=0.796), seedling dry weight (r=0.277) and seedling vigor index (r=0.977), respectively. Plumula length had significant positive correlations with all related properties, seedling length (r=0.953), seedling fresh weight (r=0.856), seedling dry weight (r=0.189) and seedling vigor index (r=0.945), respectively. Significant positive correlations were observed among seedling length with seedling fresh weight (r=0.849), seedling dry weight (r=0.249) and seedling vigor index (r=0.997). The positive correlations among seedling fresh weight with seedling dry weight (r=0.198) and seedling vigor index (r=0.840) were found to be significant. And also, seedling dry weight had a significant positive correlation with seedling vigor index (r=0.254).

CONCLUSIONS

The various environmental, ecological and cyclic processes in microsphere are deteriorated due to the toxic effects of the heavy metals on the microbial community. Lead is considered to be one of the most important environmental pollutants. Therefore, in the present study, it was aimed to determine the effect of lead on seed germination and growth parameters seedlings of 11 sesame (*Sesamum Indicum* L.) genotypes. It has been shown that genotypes react differently to increased lead concentrations. It is concluded that, a significant but negative correlation was observed among lead concentrations and observed properties of all sesame genotypes. Moreover, determination of the effect of lead on germination of sesame seeds on some varieties will be able to offer preference in the selection of sesame seeds in future studies.

REFERENCES

[1] Kabir, M., Iqbal, M., Shafiq, M., Farooqi, Z. (2010) Effects of lead on seedling growth of *Thespesia populnea* L. Plant Soil and Environment. 56, 194-199.
[2] Oancea, S., Foca, N., Airinei, A. (2005) Effects of heavy metals on plant growth and photosynthetic activity. Analele Univ Al I Cuza. 1, 107-110.
[3] Järup, L. (2003) Hazards of heavy metal contamination. British medical bulletin. 68, 167-182.
[4] Hussain, A., Abbas, N., Arshad, F., Akram, M., Khan, Z.I., Ahmad, K., Mansha, M., Mirzaei, F. (2013) Effects of diverse doses of Lead (Pb) on different growth attributes of *Zea-Mays* L. Agricultural Sciences. 4, 262.
[5] Yadav, S. (2010) Heavy metals toxicity in plants: an overview on the role of glutathione and phytochelatins in heavy metal stress tolerance of plants. South African Journal of Botany. 76, 167-179.
[6] Fahr, M., Laplaze, L., Bendaou, N., Hocher, V., El Mzibri, M., Bogusz, D., Smouni, A. (2013) Effect of lead on root growth. Frontiers in plant science. 4, 175.

[7] Pourrut, B., Shahid, M., Dumat, C., Winterton, P., Pinelli, E. (2011) Lead uptake, toxicity, and detoxification in plants. Reviews of environmental contamination and toxicology: Springer. 113-136.
[8] Brynhildsen, L., Rosswall, T. (1997) Effects of metals on the microbial mineralization of organic acids. Water, Air, and Soil Pollution. 94, 45-57.
[9] Nagajyoti, P., Dinakar, N., Prasad, T., Suresh, C., Damodharam, T. (2008) Heavy metal toxicity: Industrial effluent effect on groundnut (*Arachis hypogaea* L.) seedlings. Journal of Applied Sciences Research. 4, 110-121.
[10] Kıran, Y., Şahin, A. (2005) The effects of the lead on the seed germination, root growth, and root tip cell mitotic divisons of Lens culinaris Medik. Gazi University Journal of Science. 18, 17-25.
[11] Sharma, P., Dubey, R.S. (2005) Lead toxicity in plants. Brazilian Journal of Plant Physiology. 17, 35-52.
[12] Wierzbicka, M., Obidzińska, J. (1998) The effect of lead on seed imbibition and germination in different plant species. Plant Science. 137, 155-171.
[13] Lamhamdi, M., Bakrim, A., Aarab, A., Lafont, R., Sayah, F. (2011) Lead phytotoxicity on wheat (*Triticum aestivum* L.) seed germination and seedlings growth. Comptes rendus biologies. 334, 118-126.
[14] Amin, H., Arain, B.A., Jahangir, T.M., Abbasi, M.S., Amin, F. (2018) Accumulation and distribution of lead (Pb) in plant tissues of guar (*Cyamopsis tetragonoloba* L.) and sesame (*Sesamum indicum* L.): profitable phytoremediation with biofuel crops. Geology, Ecology, and Landscapes. 2, 51-60.
[15] Islam, E., Yang, X., Li, T., Liu, D., Jin, X., Meng, F. (2007) Effect of Pb toxicity on root morphology, physiology and ultrastructure in the two ecotypes of *Elsholtzia argyi*. Journal of hazardous materials. 147, 806-816.
[16] Sengar, R.S., Gautam, M., Sengar, R.S., Garg, S.K., Sengar, K., Chaudhary, R. (2008) Lead stress effects on physiobiochemical activities of higher plants. Reviews of Environmental Contamination and Toxicology. Springer, 196, 73-93.
[17] Dey, S.K., Dey, J., Patra, S., Pothal, D. (2007) Changes in the antioxidative enzyme activities and lipid peroxidation in wheat seedlings exposed to cadmium and lead stress. Brazilian Journal of Plant Physiology. 19, 53-60.
[18] Srivastava, S., Thakur, I.S. (2006) Evaluation of bioremediation and detoxification potentiality of *Aspergillus niger* for removal of hexavalent chromium in soil microcosm. Soil Biology and Biochemistry. 38, 1904-1911.
[19] Zhao, X., Joo, J.C., Kim, D., Lee, J.-K., Kim, J.Y. (2016) Estimation of the Seedling Vigor Index of Sunflowers Treated with Various Heavy Metals. J Bioremed Biodeg. 7, 353.

Received: **07.11.2018**
Accepted: **20.06.2019**

CORRESPONDING AUTHOR

Tamer Eryigit
Van Yuzuncu Yil University,
Gevas Vocational School,
Department of Plant and Animal Production,
Van – Turkey

e-mail: tamyigit@hotmail.com