Effect of Vermicompost fertilizer and Arbuscular mycorrhiza on physiological and morphological characteristics of soybean (M9 variety) under cadmium chloride toxicity

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ABSTRACT

In order to evaluation the effect of vermicompost fertilizer and Arbuscular mycorrhiza on physiological and morphological characteristics of soybean (M9 variety) under cadmium toxicity a pot experiment was done in greenhouse of Yasouj university in summer of 2012. Treatment arrangement was a factorial based on completely randomized design with three replications. The treatments included Arbuscular mycorrhiza in two levels (inoculation and non-inoculation with soil), vermicompost fertilizer in two levels (application and non-application in amount of 5% of soil weight) and cadmium chloride in five levels (0, 20, 40, 80 and 160 mg.kg⁻¹ of soil). Result showed that increasing concentrations of cadmium chloride significantly increased leaf proline and soluble sugars content. In addition, increasing of cadmium chloride concentration decreased plant height, leaf area, leaf soluble protein, chlorophyll and carotenoid content significantly. Application of vermicompost fertilizer and mycorrhiza decreased the toxic effects of cadmium chloride so that with application vermicompost fertilizer, plant height, chlorophyll content and carotenoid leaf increased and application of mycorrhiza increased leaf soluble protein significantly.

INTRODUCTION

Soil pollution is the increment of natural and synthetic chemical concentration in the soil profile due to human activities. Effects of pollution on plants depend on the total amount of soil pollution, specifically on the proportion available to the plant as well as the plant’s ability to absorb pollution and transfer it from soil to root. One of the important ecological pollutions is the one caused by heavy metals. In agricultural farms, heavy metal pollution due to soil treatment with polluted wastewater and indiscriminate use of phosphate fertilizers containing cadmium is a growing concern. Heavy metals are of great ecological and biological importance due to high toxicity, durability and accumulation in living tissues. Including heavy metals that are toxic to plants, lead and cadmium can be named. The critical concentration of cadmium in Iran’s soil is 5-30 ppm[17]. Although cadmium is not necessary for plant growth, this metal is easily absorbed through root skin and then enters to plant tissue by symplast or apoplast pathway. In most plant species, cadmium is aggregated in the root and some proportion of it is transferred to leaves. Retarded growth of plants is reported as a toxicity symptom of cadmium [1]. Cadmium competed calcium due to similarities of physical and chemical properties in root absorption stages and it disrupts the vital reactions by replacing the calcium place [5]. The conventional physicochemical methods used for polluted soil purification are not only costly, but also due to the destruction of soil structure, the application of agricultural farms is decreased for crop production and they have limited application at a widespread level.

In recent years, new sources of soil organic matter’ suppliers have been greatly considered due to urbanization and industrialization, particularly in developing countries and in this regard, using organic fertilizers and plant residues is a cost-effective and accessible method for reduction of metal concentration in plants and enhancement of soil and plant fertility. One of these fertilizers is vermicompost which is a bio-organic fertilizer that has been formed through slow and steady passing of decomposing organic matter in worm gastrointestinal system [4]. Arbuscular mycorrhiza (AM) fungi establish a direct connection between soil and...
plant roots, thus plant efficiency can affect phytoremediation through the impact on accessibility of heavy metals and high plant tolerance. The mechanisms that AM fungi applies for the reduction of heavy metal tension include chelation and immobilization of heavy metals in external mycelium, mineral nutrition improvement specially phosphorus, change of rhizosphere PH, gene expression regulation of metal carriers, and so on [6].

From among crops, as the next important products, oil seeds play an important role in food schedule around the world. As a result of climate variations in Iran, there is a possibility for cultivating many oilseeds such as soybean, which is of great importance industrially and economically. Soybean is a good source of protein and oil and in biochemical studies; nitrogen fixation in stabilizer nodes of root formed by Rhizobium japonicum bacteria is very important [12].

Regarding the issues reviewed, the necessity of research on the concerns and problems of soil pollution is felt more than ever, so according to positive impacts of bio-fertilizers and mycorrhiza fungi on the growth and some physiological characteristics of plants, this study was performed with the purpose of investigating the effect of vermicompost and mycorrhiza fungi on soybean plant reaction to the toxicity of cadmium chloride.

Methodology:
In the summer of 2012, the experiment was conducted in a greenhouse at Yasouj University, Iran. This experiment was factorial performed in a completely randomized design with three replications in which treatments included AM fungi (at two levels of inoculation and non-inoculation in soil), Vermicompost fertilizers at two levels (without its application and with its application at the rate of 5% of soil weight), and cadmium chloride at five levels (0, 20, 40, 80, 160 mg.kg⁻¹ of soil). Experimental units included pots with a diameter of 45 cm and height of 30 cm. Cadmium chloride treatments were sprinkled to the mixture of vermicompost and sterile soil and then each pot was filled by soil which was carefully sieved and disinfected in a way that the surface of each pot was 5 cm away from its bottom. For a month, the pots’ moisture was maintained at the farm capacity until planting time to reach equilibrium [21]. Before planting, two grams of NPK chemical fertilizers were added to the pot for supplying nutrients for the plant, and during the planting, 2 grams per each pot of Glomus mossae species of AM fungi was mixed with soil (soil weight of each pot was 6 kg). In each pot, 6 to 8 seeds of soybean were placed in the depth of 3 cm and after emergence and establishing plant, three plants were maintained by the elimination of extra plant in each pot and they were protected in the pot until the production was completed. In this experiment, the traits of chlorophyll amount and leaf carotenoids [2], proline [14], soluble sugars of leaf [7], the soluble protein of leaf [8], and height plant and leaf area were measured. To measure the morphological properties in the sheathing stage, plant height and leaf area were measured. To measure physiological properties, in the full flowering stage, a sample of experimental treatments was prepared. Samples were selected from among the youngest fully developed two-leaves. Data analysis was performed in SAS software. Average comparisons were conducted according to Duncan’s multi-range test at 5% probability level.

Finding:
Plant height:
The results of variance analysis indicated that the effect of cadmium chloride, mycorrhiza fungi and vermicompost fertilizer on plant height became significant. Moreover, among interactions, only cadmium chloride and mycorrhiza interaction was significant for this property (Table 1). The mean comparison effect of vermicompost fertilizer on plant height indicated that the highest and lowest values of this property were related to the application level (45.37 cm) and not application of vermicompost (39.62 cm), respectively (Table 2). The Mean comparison interaction of cadmium chloride and mycorrhiza fungi on this property showed that by the increment of cadmium chloride concentration, the value of plant height was decreased, and by application of mycorrhiza, it was increased. As a result, the maximum value of plant height (45.35 cm) was related to the treatment of non cadmium chloride and mycorrhiza application and the minimum value (38.97 cm) was for the treatment of 80 mg.kg⁻¹ of cadmium chloride and non-application of mycorrhiza (Table 3).

Khalighi Jamal-Abad and Khara (2007) found that due to toxicity of cadmium concentration increment, the height of wheat was decreased. In case of alfalfa, by increasing cadmium chloride concentration, the number of nodes and distances between internodes was decreased (14%), which leads to reduced plant height [20]. The reviews showed that this metal affects the division and growth of cells, total growth plant, cell division of meristem region and the regulation of plant growth and development that it is resulted in the reduction of node’s number and their distance and thereby the height is decreased [5]. In a research by Subramanian et al. (2006) conducted on tomato (Lycopersicon esculentum), the results indicated that plant root symbiosis with mycorrhiza (Glomus intraradices) contributes to a significant increment of plant height compared to the treatment of control without symbiosis.

Khalighi Jamal-Abad and Khara (2007) also reported that the reduction of wheat plant height in mycorrhizal plant resulting from the increment of cadmium concentration was generally less than the control plant. Therefore, better growth of mycorrhizal plants can be due to the reduction of toxicity effects of cadmium.
The tolerance of microorganisms (mycorrhizal fungi) of heavy metals may have many reasons including secretion of extra.

Table 1: Analysis of variance of soybean traits affected by cadmium chloride, mycorrhiza and vermicompost

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Leaf Area (cm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cadmium Chloride (A)</td>
<td>210.85</td>
</tr>
<tr>
<td>A × B</td>
<td>220.05</td>
</tr>
<tr>
<td>A × C</td>
<td>197.56</td>
</tr>
<tr>
<td>A × B × C</td>
<td>209.82</td>
</tr>
<tr>
<td>Non Application</td>
<td>152.64</td>
</tr>
<tr>
<td>Application</td>
<td>175.32</td>
</tr>
</tbody>
</table>

ns, * and **: No significant, significant on probability of 5 and 1%, respectively

Table 2: Mean comparison of vermicompost effect for some soybean characteristics

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Leaf Area (cm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non Application</td>
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</tr>
<tr>
<td>Application</td>
<td>175.32</td>
</tr>
</tbody>
</table>

ns, * and **: No significant, significant on probability of 5 and 1%, respectively

Table 3: Mean comparison interaction of cadmium chloride and Mycorrhiza on plant height

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Plant Height (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>42.40 bc</td>
</tr>
<tr>
<td>20</td>
<td>43.80 abc</td>
</tr>
<tr>
<td>40</td>
<td>41.38 bc</td>
</tr>
<tr>
<td>80</td>
<td>41.73 bc</td>
</tr>
<tr>
<td>160</td>
<td>39.51 bc</td>
</tr>
</tbody>
</table>

ns, * and **: No significant, significant on probability of 5 and 1%, respectively

Leaf Area:

For this property, cadmium chloride and vermicompost fertilizer had significant effects and among interactions, cadmium chloride and vermicompost as well as mycorrhiza and vermicompost interaction on this property showed significant effect (Table 1). Mean comparison interaction of cadmium chloride and vermicompost on leaf area showed that by increasing cadmium chloride concentration, the leaf area was significantly decreased, but the application of vermicompost fertilizer resulted in an increase of this property, so that at all levels of cadmium chloride concentration, except the concentration of 160 mg kg⁻¹, the increment of leaf area resulting from the application of vermicompost fertilizer was significant and also the highest amount of leaf area (220.05 cm²) was observed without cadmium chloride and the application of vermicompost fertilizer treatment and its lowest amount (148.85 cm²) in 80 mg kg⁻¹ of cadmium chloride and non application of vermicompost fertilizer treatment (Table 4). Likewise, the mean comparison mycorrhiza and vermicompost interaction for this property indicated that the highest amount of leaf area (209.82 cm²) was related to non-inoculation of mycorrhiza fungi and the application of vermicompost fertilizer treatment and the lowest amount (167.32 cm²) belongs to non-inoculation of mycorrhiza fungi and non-application of vermicompost fertilizer treatment, although there is no significant difference between this treatment and mycorrhiza inoculation and non-application of vermicompost (Table 5).
According to Soltani et al. (2006), leaf area in the rape was decreased under cadmium tension. In the concentrations of 400, 600 and 800 μM of cadmium, the leaf area significantly decreased, because cadmium decreased the activity of photosynthesis and leaf development, thereby the inward pressure is reduced. This reduction shrinks the cells and the distance of intercellular in plants under the cadmium tension through the reduction of elasticity of cell walls. Seeds inoculation with mycorrhiza fungi can develop the root of soybean; hence, less nutrition is transferred to upper limbs of plant and thereby the number of leaves and their area will be decreased. Also, in the presence of mycorrhiza fungi with bacteria of vermicompost, an antagonistic impact can be observed, and plant growth and leaf area decreased. Arancon et al. (2004) conducted an experiment on strawberry (Fragaria ananasa) using the values of 0, 5 and 10 ton.ha⁻¹ of vermicompost. It was observed that the application of various values of vermicompost significantly increased the leaf area and the biomass of strawberry shoot compared to the control plants. They attributed this superiority to the increase of soil microbial population and the production of stimulant materials such as plant hormones resulting from the activities of earthworms in vermicompost.

**Leaf Proline:**

Among performed treatments, the effect of all treatments (cadmium chloride, mycorrhiza and vermicompost) on the amount of proline became significant, but the interactions of treatments with this property were not significant (Table 1). Regarding the mean comparison of cadmium chloride effect on this property, it can be observed that the increment of cadmium chloride concentration leads to significant rise, so that the highest amount of leaf proline (1.60 μmol.g⁻¹ of leaf fresh weight) has achieved in the treatment of 80 mg/kg of cadmium chloride and the lowest amount of this property (1.03 μmol.g⁻¹ of leaf fresh weight) belonged to the treatment without cadmium chloride. However, there was no significant difference between the treatment of zero and 20, as well as the treatments of 80 and 160 mg.kg⁻¹ of cadmium chloride (Table 6). In this study, the amount of proline decreased through the application of vermicompost and mycorrhiza fungi, so that the application of vermicompost and also soil inoculation with mycorrhizal fungi decreased this property by 19% and 21%, respectively (Tables 2 and 7). It has reported that in the lentil plant under the treatment of different concentrations of cadmium, in the 40 μM concentration, the value of proline showed 48% increment comparing the control [9]. The proline is aggregated in the plants under the cadmium stress and there is a special relationship between proline aggregation and the shortage of water formed due to heavy metals' effect. Presumably, proline aggregation in the plants under the cadmium treatment has a relationship with resistance mechanism against the osmotic changes or reduction in the activity of electron transfer system in the plants or some parts of plant. The reduction of metabolism activity and the destruction of electron transfer path in photosystem II contribute to NADH aggregation. Because for the synthesis of a proline molecule of glutamic acid, two NADH is required, proline synthesis may be a mechanism for acidity and NADH aggregation reduction [15]. Apparently, through the reduction of cadmium absorption, the application of mycorrhiza fungi and vermicompost fertilizers prevents from more proline production in the soybean.
Leaf Total Soluble Sugar:
The results indicated that the effect of cadmium chloride and mycorrhiza fungi on the leaf total soluble sugar amount was significant; moreover, mycorrhiza and vermicompost interaction showed significance (Table 1). According to the mean comparison of cadmium chloride effect, it can be observed that the increment of cadmium chloride concentration leads to a significant rise, so the highest value of soluble sugar (5.02 mg g\(^{-1}\) of leaf fresh weight) was achieved in the treatment of 160 mg kg\(^{-1}\) of cadmium chloride and the lowest value (3.39 mg g\(^{-1}\) of leaf fresh weight) was observed in the treatment without cadmium. However, there was no significant difference between the control treatment and the levels of 20 and 40 mg kg\(^{-1}\) of cadmium chloride; as well, there was no significant difference between the levels of 80 and 160 mg kg\(^{-1}\) of cadmium chloride (Table 6). The mean comparison of mycorrhiza and vermicompost interaction on the amount of leaf total soluble sugar demonstrated that the application of mycorrhiza fungi contributed to a decline in soluble sugar. Hence, the highest value of soluble sugar (5.06 mg g\(^{-1}\) of leaf fresh weight) was observed in the treatment of non-inoculation of mycorrhiza and vermicompost application and the lowest value (3.19 mg g\(^{-1}\) of leaf fresh weight) was for the treatment of inoculation of mycorrhiza and vermicompost application (Table 5).

As the results of rape plant indicated, soluble sugar value was significantly increased by the increment of cadmium concentration [22]. Karimi and Nojavan (2009) indicated that as cadmium concentration increased, the value of soluble sugar in lentil plant increased, in such a way that in concentration of 160 \(\mu\)M of cadmium, the value of soluble sugar was increased by 80% compared to the control. The reason for this increase might be decreased respiration and increased activity of sugar decomposition enzymes such as invertaz and sucrose synthase, which led to decreasing sugar use, on the one hand, and their increased production, on the other. In another research, as cadmium chloride concentration increased in the growth environment, the value of soluble sugar of safflower plant gradually increased. Cadmium decreased water transfer in safflower; as a result, the concentration of this substance was increased in these cells and reduction of water in cells led to increment of soluble sugar concentration in the leaf. Thus, the plant could utilize its maximum power to maintain the aqueous value of plant through observing osmotic conditions [13]. It is reported that cadmium toxicity increases with the concentration increment in experimental solution, the value of soluble sugars in the root and shoot of the plant are increased either in mycorrhizal and non- mycorrhizal plant, but this increase is more sensible in mycorrhizal ones [10]. In addition to increasing the availability of plant nutrients, vermicompost is performed to increase the activity of soil positive microorganisms (such as mycorrhiza), mycorrhiza prevents from absorption of this metal due to cadmium complex in its mycelium and also mycorrhizal increases the water of cells, due to the increase of total root area, creating a wide mycelium cover surface in the root and hair-like fibers region and the increase of nutrients and water uptake, it decreases the osmotic pressure and consequently the value of soluble sugar in the leaf is decreased [4].

Leaf Soluble Protein:
The effect of cadmium chloride and mycorrhiza fungi on value of leaf soluble protein was significant, but the effect of vermicompost fertilizer and treatments’ interaction did not show any significant effect (Table 1). The mean comparison effect of cadmium chloride for soluble protein amount of leaf indicated a decline of this property as the concentration of cadmium chloride increased. So, the maximum value of leaf soluble protein (206.50 mg g\(^{-1}\) of leaf fresh weight) was observed in without cadmium chloride treatment, whereas the minimum value (147.03 mg g\(^{-1}\) of leaf fresh weight) was in 160 mg kg\(^{-1}\) of cadmium chloride treatment (Table 6). According to table 7, through soil inoculation with mycorrhiza fungi, the value of leaf soluble protein was increased in such a way that the minimum rate of this trait (162.76 mg g\(^{-1}\) of leaf fresh weight) is observed in non-inoculation of mycorrhiza and the maximum value (199.06 mg g\(^{-1}\) of leaf fresh weight) in mycorrhizal

### Table 6: Mean comparison of cadmium chloride effect on physiological traits of soybean

<table>
<thead>
<tr>
<th>Edible CmuimadA (mg.kg(^{-1}) soil)</th>
<th>Leaf Proline (μmol.g(^{-1}) leaf fresh weight)</th>
<th>Leaf Soluble Protein (mg.g(^{-1}) leaf fresh weight)</th>
<th>Leaf Total Soluble Sugar</th>
<th>Leaf Carotenoid</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1.03 c</td>
<td>206.50 a</td>
<td>3.13 a</td>
<td>0.88 a</td>
</tr>
<tr>
<td>20</td>
<td>1.12 c</td>
<td>203.16 a</td>
<td>2.90 ab</td>
<td>0.81 ab</td>
</tr>
<tr>
<td>40</td>
<td>1.29 b</td>
<td>192.07 ab</td>
<td>2.72 bc</td>
<td>0.75 bc</td>
</tr>
<tr>
<td>80</td>
<td>1.60 a</td>
<td>157.79 bc</td>
<td>2.76 bc</td>
<td>0.74 bc</td>
</tr>
<tr>
<td>160</td>
<td>1.51 ab</td>
<td>147.03 c</td>
<td>2.51 c</td>
<td>0.69 c</td>
</tr>
</tbody>
</table>

Mean within columns with different letters are significantly different at 5% for a Duncan Multiply Range Test.

### Table 7: Mean comparison of Mycorrhiza effect on leaf proline and leaf soluble protein

<table>
<thead>
<tr>
<th>Mycorrhiza</th>
<th>Leaf Proline (μmol.g(^{-1}) leaf fresh weight)</th>
<th>Leaf Soluble Protein (mg.g(^{-1}) leaf fresh weight)</th>
</tr>
</thead>
<tbody>
<tr>
<td>noitaluconi noN</td>
<td>1.45 a</td>
<td>162.76 b</td>
</tr>
<tr>
<td>noialuconl</td>
<td>1.17 b</td>
<td>199.06 a</td>
</tr>
</tbody>
</table>

Mean within columns with different letters are significantly different at 5% for a Duncan Multiply Range Test.
inoculation treatment. Khudser et al. (2001) reported the decrease of total protein value in the Cajanus Cajan by cadmium concentration increase. Heavy metals are toxic for plants, and with production of oxygen free radicals damage the protein and amino acids structure. In addition, oxygen free radicals have a high tendency to protein and cause oxidation. Additional cadmium prevents the Rubisco activity of key enzymes in Calvin cycle and contributes to solution protein reduction [11]. Protein content depends on the difference between synthesis and its decomposition. Produced oxygen free radicals, during the stress, because of their high tendency to integrate with proteins, destroy cell membrane, nucleic acid, and cell proteins. Cadmium causes the control and disruption of sulphhydryl groups of proteins through connection to them [11]. Noorani Azad and Kafilzadeh (2011) indicated that cadmium leads to reduction of protein production in safflower and stops the growth with disturbance in nitrogen metabolism through controlling the activity of the enzymes, such as glutamine synthesis, glutamate synthesis, nitrate reductase, and nitrate reclamation process. In the study by Repetto and Bastel-Corre (2003) on the protein expression between two types of pea with different sensitivity degree with and without Glomus mosseae, it is observed that this fungus leads to resistance increase sensitive to metal and this issue addresses to probable mycorrhiza fungi role in helping gene expression of protein producing. In areas contaminated by heavy elements (cadmium), mycorrhiza can prevent plants from absorbing these elements and it increases the production while restoring the soil. This mechanism is due to the complexion of these elements in fungi mycelium which inhibits metal cation absorption [4].

Total Chlorophyll:
According to the table of data variance analysis, it is observed that cadmium chloride and vermicompost fertilizer effect on the value of total chlorophyll was significant, but the effect of mycorrhiza on this property did not show significant; none of these interactions was significant for total chlorophyll (Table 1). The average comparison of treatments for the value of chlorophyll showed that the increase of cadmium chloride concentration has led to a significant decline of this property and the maximum and minimum value of total chlorophyll was respectively for the zero level (2.51 mg.g\(^{-1}\) of leaf fresh weight) and 160 mg.kg\(^{-1}\) of cadmium chloride (3.13 mg.g\(^{-1}\) of leaf fresh weight) (Table 6). By application of vermicompost organic fertilizer, the amount of this property showed an ascending process (7.02%) (Table 2). Popova et al. (2007) expressed that plant chlorophyll and carotenoid content is decreased under cadmium stress conditions. Accordingly because of stress, first, the leaves are chlorosized and then begin to fall. The findings of Noorani Azad and Kafilzadeh’s (2011) research indicated that with the increase of cadmium concentration in the growth environment, the amount of chlorophyll and carotenoid of safflower leaves was decreased. In fact, cadmium tension increased oxygen free radicals in chloroplasts, thus chloroplast membrane was damaged and lost its vital viability. The reduction of leaves chlorophyll storage is due to inhibition of different stages of chlorophyll biosynthesis. The inhibition of chlorophyll biosynthesis is presumably due to inhibition of forming reductase proto-chlorophyll. Additionally, in the leaves under cadmium stress, photosystem II activities are disrupted that its reason is inhibition of photosystem II protein synthesis in the duplication step which leads to photo-oxidation of newly formed chlorophyll. The reduction of chlorophyll value in the plant treated with cadmium is because of the increment of destructed enzymes of chlorophyll (Baryla et al., 2001).

Vermicompost includes various nutrients for plants which releases these elements for plant nutrition on time. This organic fertilizer is well transformed, while its porosity, ventilation, drainage and moisture-holding capacity are excellent. From a qualitative perspective, it is rich in humic substances and absorbable elements for plants such as like nitrogen. Nitrogen, due to the role of production and export of cytokinin from the root to the shoots, increases the speed of cell division in plant growth. Furthermore, nitrogen indirectly affects the gibberellin hormone by cytokinin. As a result, it increases the growth of branches’ end parts, young leaves and photosynthesis. Through nitrogen participation in chlorophyll structure, there is a positive and significant relationship between leaf nitrogen and the value of chlorophyll.

Leaf Carotenoid Content:
From among the treatments conducted, only the effect of cadmium chloride became significant for this property, but it was not the same for the vermicompost fertilizer, mycorrhizal fungi and also interactions of treatments (Table 1). The mean comparison cadmium chloride effect on leaf carotenoid content indicated that as the amount of cadmium chloride increases from 0 to 160 mg.kg\(^{-1}\), there can be seen a decline in leaf carotenoid. So that, the minimum and maximum of this property is related to level of 160 mg.kg\(^{-1}\) of cadmium and the level of without cadmium chloride, respectively (Table 6). Other studies have indicated that cadmium decreases the value of carotenoid in organic plants [19]. The amount of chlorophyll and carotenoid of safflower is decreased by increase of cadmium concentration in growth environment [13]. Its reduction relates to suppression of stimulated chlorophylls by carotenoids and thus it breaks down their structure. Carotenoids decrease toxic effects of free radicals in multiple levels, among which it can be addressed to reaction with stimulated chlorophylls for inhibition of forming oxygen active radicals. Carotenoids are eliminated as a protection system against induced oxidative tension [19].
Conclusion:
The results showed that as the concentration of cadmium chloride increased, the toxicity effects of cadmium element appeared in the plant, while the soybean showed some changes in reaction to this toxicity, such as increase in its proline concentration and soluble sugars, and reduction of leaf soluble proteins, chlorophyll content and leaf area. The application of vermicompost fertilizer and soil inoculation with mycorrhizal fungi through the decrease of cadmium absorption in the plant was found to moderate these changes in the soybean to some extent.

REFERENCES


