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The efficacy of banana compost as biofertilizer on barley (*Hordeum vulgare)* plants grown on soil polluted with cadmium.

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ABSTRACT

Heavy metals are one of the important environmental pollutants and their toxicity is a great concern for plant growth. Cadmium (Cd) is a toxic heavy metal ion that is accumulated in the soil as a consequence of human activities. Plants own strategies to control the concentration of metal ions inside the cell to minimize the possible harm that could cause by being subjected to nonessential metal ions. However, the accumulation of cadmium concentration in the plant cells led to frail its resistance. In this study, grains of barley (*Hordeum vulgare*) were exposed to two Cd concentrations (150 and 300 ppm) against untreated control. Cadmium treatment caused a reduction in plant length at the highest level of Cd (300 ppm). The inhibition of chlorophyll content due to indirect Cd effects on the content of essential nutrients and osmoprotectants, including soluble sugars (SS), soluble proteins (SP), total free amino acids (TAA) and higher accumulation in proline contents. Excessive cadmium accumulation increased malondialdehyde (MDA) level in shoot and root systems disrupting the cell membrane. Data of the present study indicated that the usage of banana compost as a biofertilizer alleviated the drastic effect of cadmium stress in barley plants as it promoted growth performance, enhanced photosynthetic pigments, SS, SP, TAA and reduced proline. Banana compost balanced the absorption and translocation of mineral homeostasis from roots to shoots. Results indicated also that compost supplementation reduced lipid peroxidation. Our results may help shed light on plant adaptation to cadmium stress using different organic fertilizers, however different plant species still need further research.

INTRODUCTION

Urbanization speed that occurs all over the world increases the spread of chemicals including heavy metals. Heavy metal pollution possess a serious hazard to humans health, and its uptake into plants is the primary way through which it can go into the food cycle [1].

Cadmium (Cd) is a toxic non-essential element to all living organisms including human beings and plants. Due to its high solubility and mobility, Cd is dangerous even at a very low concentration owing to high the toxicity and bioaccumulation [2, 3]. However, Cd can unawares enter the soil as a result of geological and anthropogenic activities. 13,000 tons of Cd are added to the environment every year by mining, smelting, fertilizers' treatments with phosphate, sewage sludge contamination, and wastewater irrigation [4].

Cd is a mobile heavy metal that can be taken easily by plants and then pass into the food chain [5]. Causing a serious health issue for humans. Thus, soils contaminated with toxic heavy metals and translocations of these metals into the food chain have critical environmental and biological concerns [6]. Understanding the plant responses to the heavy metal is important and a fundamental part of making the crops stress-tolerant. This lethal element inhibits soil biological activity and plant metabolism even at a little concentration, consequently, the plant root and shoot lengths declines besides, the dry weight of both shoot and root systems is also reduced [7]. Moreover, the plants exposed to excessive amounts of Cd in the soil show many toxic symptoms, such as retardation in growth especially root growth, disturbances in mineral nutrition, carbohydrate metabolism and in turn strongly reduction in biomass production [8- 10].

Cd stress destabilizes the biochemical and physiological processes of crop plants by disrupting photosynthetic traits, changing the osmotic adjustment and ionic homeostasis, producing toxic oxidants, and counteracting essential metabolic pathways [11]. Additionally, Cd injures the photosynthetic apparatus, so it indirectly reduced pigment content in the plants [12, 13].

The toxicity of Cd causes ionic imbalance, osmotic stress, disruption of lipids in the form of malondialdehyde (MDA) and reduces uptake of essential nutrients by roots which in consequence led to disorders in the physiological and biochemical pathways in plants [14- 16]. These changes depend on the plant species, the concentration of Cd, and the duration of exposure [17].

Thus, numerous strategies have been discussed for the successful controlling of Cd-contaminated soils. Organic farming is one of these strategies that provide crops with biomaterial and avoids the harmful effects of chemical one. Moreover, it increases soil fertility and reduces environmental pollution [18, 19]

This idea of using banana compost depends on several facts: (1) generally, biofertilizers improved plant growth via the activities of microorganisms, i.e. alteration of nutritionally significant elements/compounds, (2) production of active ingredients, especially phytohormones (e.g. cytokinins, auxins, gibberellins, etc.), amino acids and proteins (3) combination of compost to the soil might also be effective in reducing Cd toxicity [20] and(4) enriched plant physiological status with developments in quantity and quality of crop productions [21].

Using waste product is one of the cornerstones of organic farming. This means returning to the soil. Several positive effects of applying bio-fertilizers were due to their own different nutrients, increase in the fertility of the soil, higher percentage of proteins, and natural plant growth regulators such as cytokines [22, 23]. Additionally, they have a great amount of symbiotic and non-symbiotic bacteria, and possess active microorganisms hydrolyzing the insoluble to soluble ones. Banana waste materials are rich in nutrients and minerals especially nitrogen, phosphorous, and potassium [24].

Among cereal plants that exhibit great adaptability toward contaminated soils with heavy metals is barley [25]. Cultivation of barley (*Hordeum vulgare* L.) in Egypt considers one of the ancient and most important winter crops which played a substantial role in the progress of agriculture. Nowadays, cultivated barley is grown in much more diverse environmental conditions as compared to other cereal crops [26]. Barley was principally used as human food that has a great value as feed, including both grain and straw, and recently it was utilized for animal feed and bedding [27]. Cd-exposed cereal crop cultivars around the world can store high Cd concentrations in grains. More than 40% of Cd may be absorbed and translocated to the plant aerial parts and consequently may directly (grains) or indirectly (animals) affect human health [28].

This study focuses on the ameliorative role of banana compost in mitigating the drastic effect of Cd stress and enhancing the stress tolerance mechanism in barley plants cultivated in soil contaminated artificially by cadmium. Subsequently, barley displayed adaptive characteristics to some extent for survival in soil contaminated by Cd. Banana compost improved the growth, photosynthetic and physiological characteristics of barley under mild and higher Cd treatments.

MATERIALS AND METHODS

Plant growth and experimental design

The experimental plant material used in this investigation was barley plants (*Hordeum vulgare* L., cv. Giza 123), were obtained from the Agronomy Department, Faculty of Agriculture, South Valley University. It was used pot culture in the wire-house experimental farm of South Valley University, Qena city, Egypt (26°11′32"N, 96 32°44′43"E). Barley grains (equal-sized and -weighted) were surface-sterilized with 70% ethyl alcohol for 5 minutes and then rinsed 3 times with sterile distilled water. They were germinated in plastic pots (20 seeds/ pot) filled with 8 kg of dried soil (3:1 sand to clay v/v) at the experimental farm of the Botany Department, Faculty of Science at Qena, South Valley university under field conditions. Preliminary experiments were carried out to choose the dose of $CdCl_2$ and the best concentration of banana compost that should be added to the soil. After 10 days, only five healthy plants of similar size were kept in each pot. Two sets of pots were prepared (9 pots/set). Set 1 was irrigated with 0,150 and 300 ppm $CdCl_2$, respectively, and served as control. In set 2 the soil was mixed with 10% banana compost and irrigated with the same levels of $CdCl_2$.

Physical and chemical properties of the soil

Particle size distribution (%)		**Texture class**		**pH**	**EC (dS m^{-1})**		**Organic Matter (%)**	
Sand 70 %	**Clay 30 %**	Silt		7.21	6.2		0.98	
Cations (Kg/L)					**Anions (Kg/L)**			
Na^{+}	K^{+}	Ca^{++}	Mg^{++}		CO_3^{-}	HCO_3^{-}	Cl^{-}	SO_4^{-}
3.53	0.65	2.5	1.55		0.01	1.19	2.97	2.89

Preparation of banana compost

The banana compost was made according to [29]. Banana waste was chopped into small parts. Make four layers of compost materials, each layer about 2-3 m in width, 30-40 cm in height, and 25 cm thick. A layer of compost material consists of three parts; banana waste, one part livestock manure, soils and urea spread on top of each other, and water was sprayed between layers. Stack the layers until the compost heap reaches 1.5 m high. The compost piles were fermented under the sun for 12 weeks [30]. The composting process depends on many factors. These factors include temperature, moisture, oxygen, particle size, carbon-to-nitrogen ratio, and the frequency and degree of turning. Compost was transported to pots by rate 1: 10 composts to soil and incorporated basely.

1.2. Analysis of banana compost

1. pH was measured by pH Meter (Compost: Water = 1: 1).
2. Nitrogen (N) was measured according to [31].
3. Phosphorus (P) was measured by Spectrophotometer.
4. Potassium (K) was measured by Atomic Absorption Spectrophotometer.
5. Organic matter was measured by the method of [32].

6. Electrical Conductivity (EC) was measured by a Conductivity meter.

Analysis of nutrient content in compost fertilizer:

Treatments	Nutrient content of banana wastes composting (%)							
Agricultural wastes and manure (ratio)	**N**	**P**	**K**	**pH**	**Organic Matter**	**EC (mS/cm)**	**TDS g/L**	**Moisture**
banana wastes manure: urea = 100 : 20 : 0.2	1.91	2.5	2.62	8.1	22.6	9.82	6.285	35.4

Plant growth measurements

Plants were harvested on the 60th day and the following parameters were measured: lengths of the shoot and root and fresh weights for shoots and roots. Samples were dried at 80 °C for 2–4 days till their dry weight remained constant. Samples were ground and stored for different chemical analyses.

Determination of pigment contents.

Chlorophyll a, chlorophyll b, and carotenoids were estimated in the fresh leaves of barley based on the technique of [33].

Determination of the physiological characteristics in shoot and root systems

The soluble sugars were extracted with anthrone-sulfuric acid [34]. The content of soluble proteins was determined according to [35]. The content of free amino acids was determined by [36]. Free proline content was determined in accordance with the description of [37]. The level of lipid peroxidation was determined in the term of malondialdehyde (MDA) by following by the protocol of [38].

Determination of different mineral ion contents

Shoot and root water extracts were prepared for minerals analysis; K, and P according to [39]. For Cd analysis, the mixed acid digestion procedure as described by [40] was used for preparing the extracts of different $CdCl_2$ levels or the plant materials. The Total contents of Cd were estimated using an atomic absorption spectrophotometer**.**

Statistical analyses

Data were statistically analyzed using SPSS version 21 software. Analysis of variance (ANOVA) was carried out using a general one-way model, and Tukey's and LSD tests were used for comparison between means. Differences were considered significant at P values < 0.05.

RESULTS

1. Effect of $CdCl_2$ and/or banana compost on growth parameters of barley plants

The shoot and root lengths of *Hordeum vulgare* plants treated with different concentrations of $CdCl_2$ and 10% banana compost biofertilizer are shown in Figure 1 and Table (1). It is clear from the table that the shoot length of the studied plants was increased at 150 ppm $CdCl_2$ by about 5.81% as compared with absolute control plants. While at 300 ppm $CdCl_2$ the shoot length of the experimental plants decreased significantly by 15.89% as compared to the absolute control plants. The root length of *Hordeum vulgare* plants was decreased progressively by increasing cadmium levels.

The application of 10 % banana compost biofertilizer on the *Hordeum vulgare* plants grown on 0.0, 150 and 300ppm $CdCl_2$ significantly increased the shoot length by 11.17%, 10.20%,and 14.01%, respectively. While in case of root length, the increase was at 300ppm $CdCl_2$ only about 40.6% as compared with the corresponding stress level.

Figure 2 shows the effect of different treatments (cadmium or banana compost biofertilizer) on fresh and dry weights of shoot and root organs of the *Hordeum vulgare* plants. Data indicated that fresh and dry weights of shoot and root organs of the *Hordeum vulgare* plants were decreased significantly by increasing Cd stress. The reduction in fresh and dry weights of shoot and root organs was proportional to the Cd stress level. When plants were treated with banana compost biofertilizers the fresh and dry weights of both organs increased significantly compared with the corresponding unfertilized plants. In *Hordeum vulgare* plants grown on 0,150 and 300 ppm $CdCl_2$ banana compost increased the fresh weight of shoot and root systems by 64.05%, 172.88%, 186.86% ,and 70.37%, 126.09%, 78.26%, respectively as compared by the corresponding stress levels. Also, banana compost increased the dry weight of shoot and root systems by 62.5%, 148.28%, 148% and 89.47%, 137.5%,and 78.28%, respectively as compared to the corresponding stress levels.

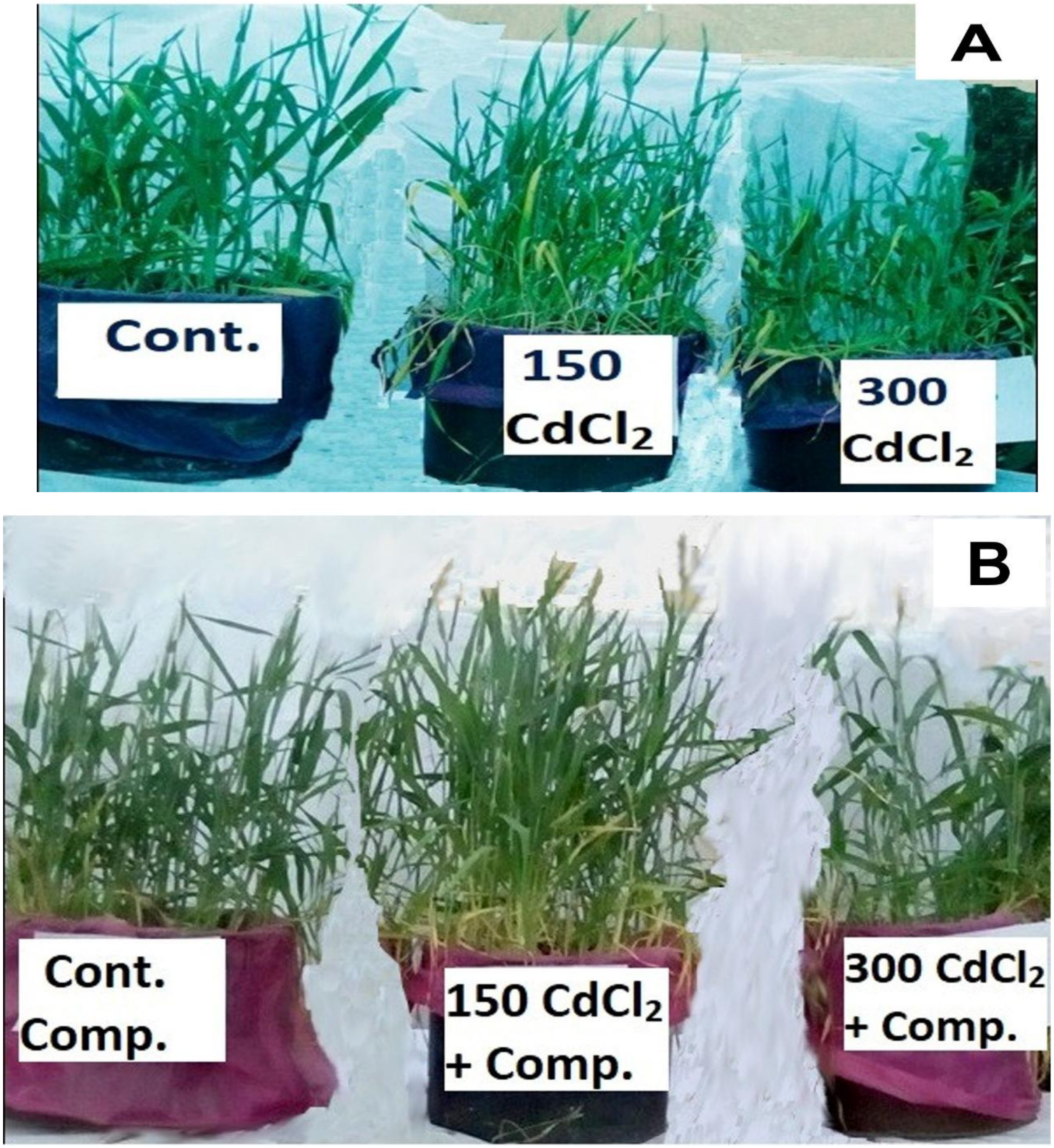

Figure 1: Photos of *Hordeum vulgare* plants treated with 0.0, 150 and 300 ppm $CdCl_2$ only (A) and treated with 10% banana compost biofertilizer (B) with the same levels of $CdCl_2$.

Table 1: Shoot and root lengths (Cm plant^{-1}) of *Hordeum vulgare* plants treated with 0.0, 150 and 300 ppm $CdCl_2$ and/or 10% banana compost, values are means± SE, n =3 for comparison between stress levels. Values with different letters are significantly different ($p<0.05$) according to Tukey's test.

Parameters	Treatment	Shoot				Root			
		Cd ppm				Cd ppm			
		0.0	**150**	**300**	**F-value**	**0.0**	**150**	**300**	**F-value**
Length	**Cont.**	$37.33^{b} \pm 0.27$	$39.5^{c} \pm 0.27$	$31.4^{a} \pm 0.12$	**2445.53****	$13.2^{c} \pm 0.1$	$12.0^{b} \pm 0.06$	$6.97^{a} \pm 0.10$	**205.875****
	Comp	$41.5^{b} \pm 0.17$	$43.53^{c} \pm 0.28$	$35.8^{a} \pm 0.21$	**1024.8****	$11.0^{b} \pm 0.12$	$11.63^{c} \pm 0.05$	$9.8^{a} \pm 0.15$	**59.727****
	L.S.D	**0.326**				**0.303**			

2. Effect of $CdCl_2$ and/or banana compost on chlorophyll contents in barley plants

The effect of Cd stress and 10% banana compost biofertilizer on chlorophyll (Chl. a), Chl. b and carotenoid of *Hordeum vulgare* plants was illustrated in Figure 3. It is clear from the figure that Chl. a, Chl. b, and carotenoids contents were increased at moderate Cd stress level (150ppm) while 300ppm Cd tress retarded the biosynthesis of pigments. When plants were treated with banana compost biofertilizer the contents of different pigment fractions increased significantly except Chl. b at the highest Cd stress level only decreased as compared with control plants. In *Hordeum vulgare* plants grown on 0.0, 150 and 300ppm $CdCl_2$, banana compost biofertilizer increased Chl. a content by 44.89%, 47.48%, and 46.27%, respectively, while the increase in case of carotenoids were 156.32%, 58.53%, and 33.57%, respectively. Finally, the stimulation in Chl. b about 193.73% and 434.01% at Cd levels (0.0 and 150ppm, respectively).

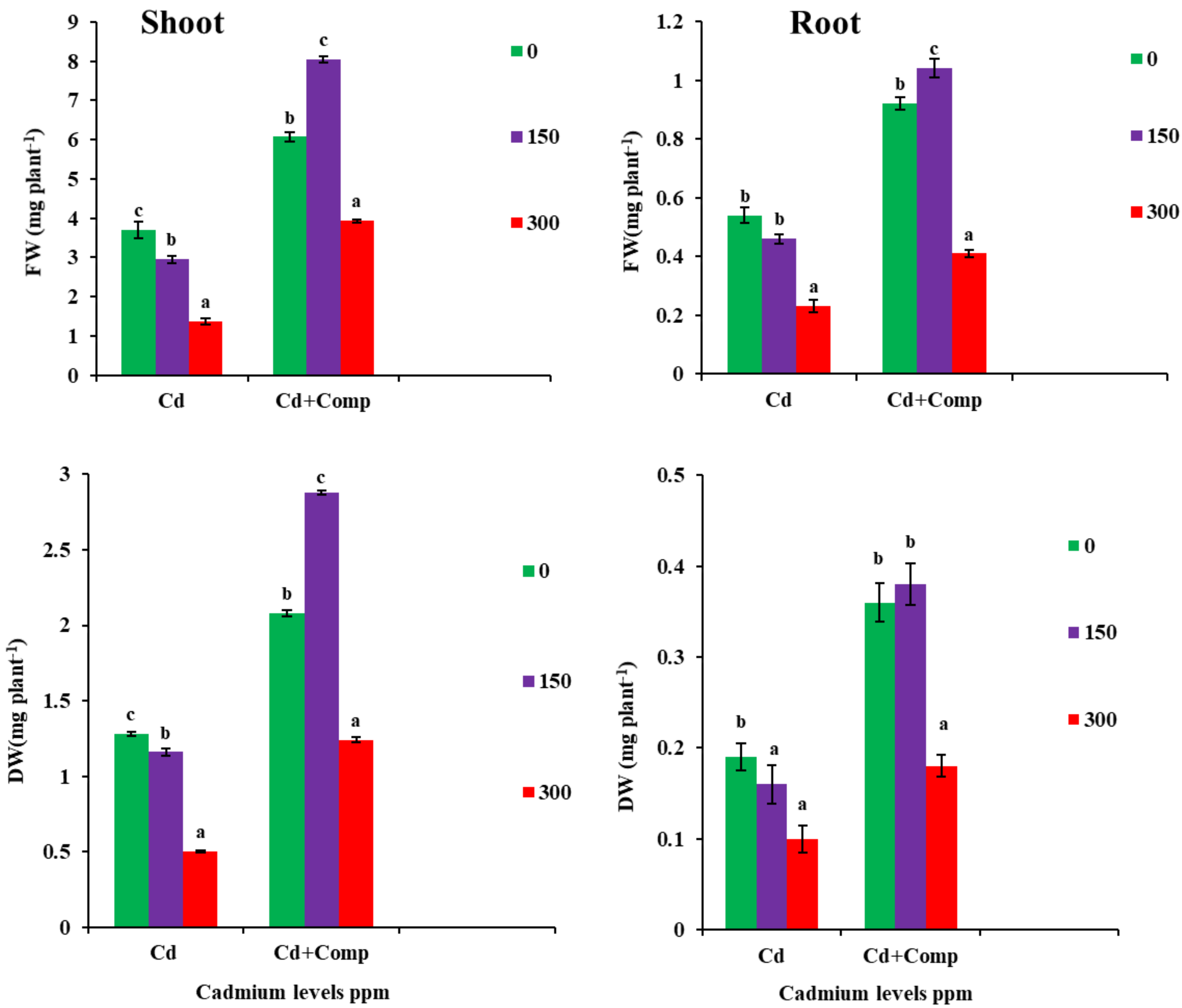

Figure (2): Fresh and dry weights in shoot and root (g plant^{-1}) of *Hordeum vulgare* plants treated with 0.0, 150, 300 ppm $CdCl_2$ and/or 10% compost, values are mean of three replicates. In each panel: for comparison between stress levels. Values with different letters are significantly different, ($P<0.05$) according to Tukey's test.

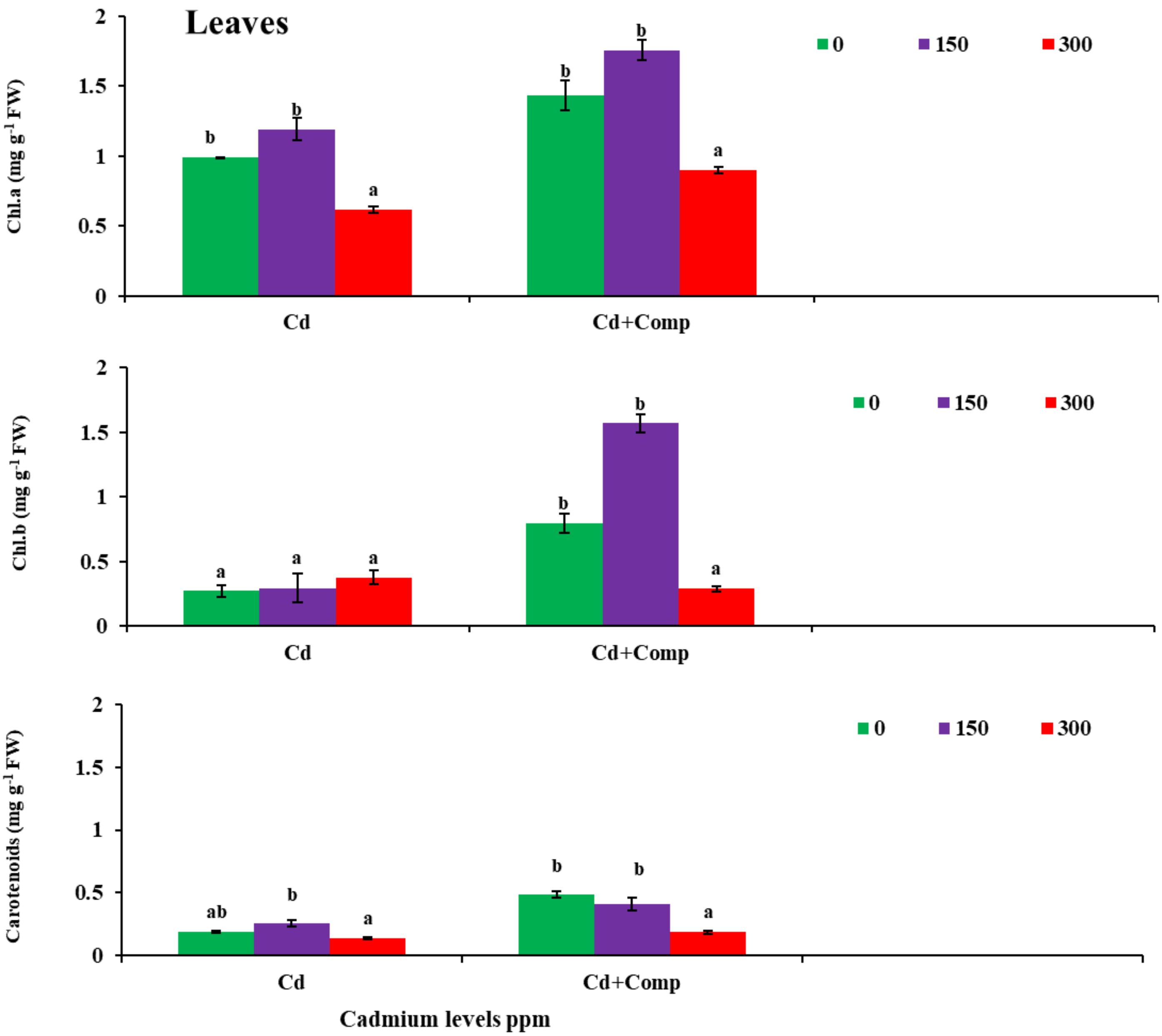

Figure (3): Chlorophyll a (Chl.a), chlorophyll b (Chl.b) and carotenoids (mg g^{-1} FW) contents of *Hordeum vulgare* plants treated with 0.0, 150, 300 ppm $CdCl_2$ and/or 10% compost, values are mean of three replicates. In each panel: for comparison between stress levels. Values with different letters are significantly different, ($P<0.05$) according to Tukey's test.

3. Effect of $CdCl_2$ and/or banana compost on soluble sugars and soluble proteins content in barley plants

Soluble sugars (SS) and soluble proteins (SP) contents in *Hordeum vulgare* plants treated with $CdCl_2$ and banana compost are represented in Figure 4. The contents of SS and SP in both shoot and root systems were increased progressively at a moderate level of cadmium then they decreased significantly with increasing cadmium levels as compared with the absolute control plants.

Bio-fertilizing with banana compost resulted in a progressive accumulation in the content of SS and SP whatever the level of Cd and the plant organ analysed in comparison with the corresponding unfertilized stress levels.

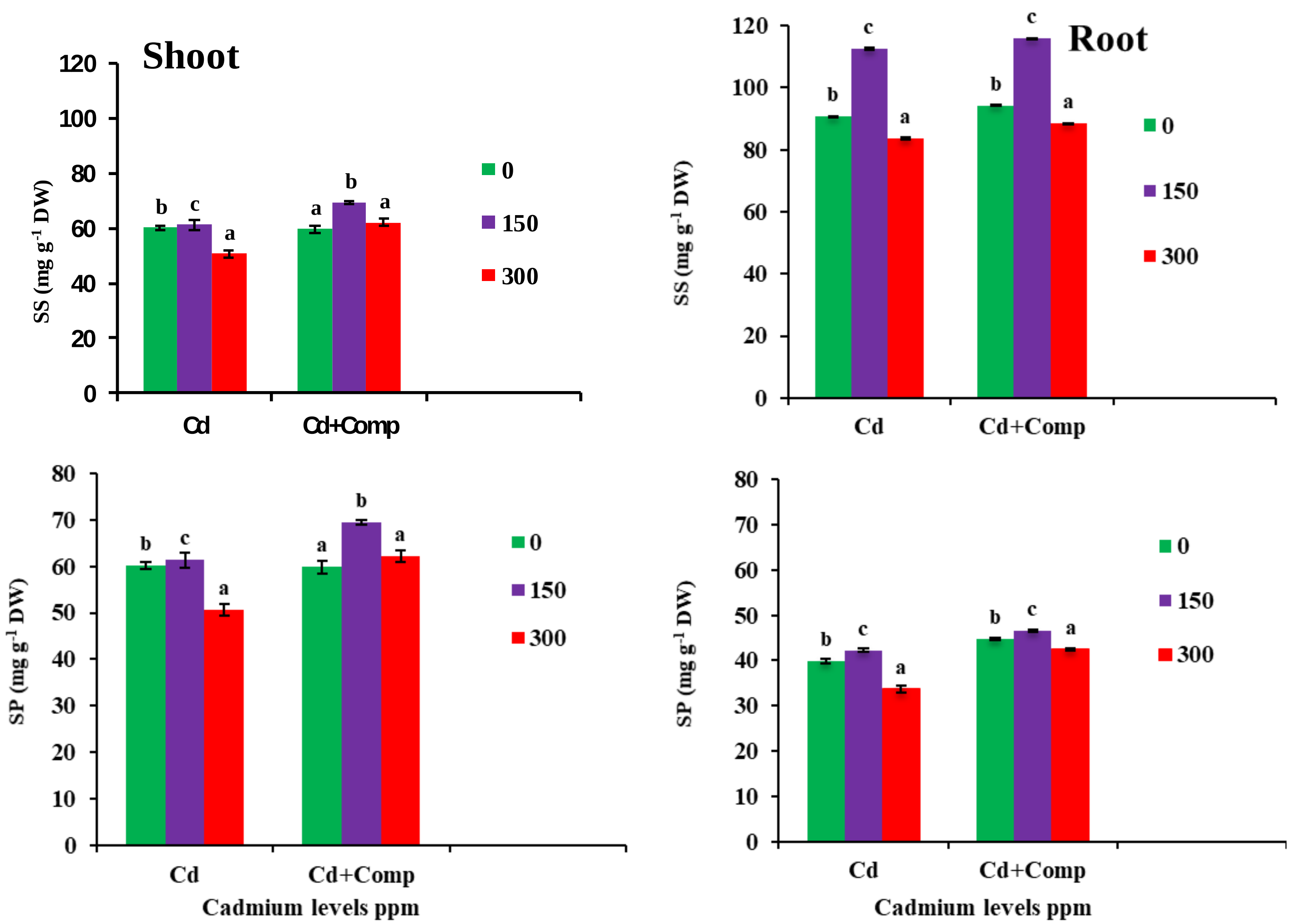

Figure (4): Soluble sugars (SS) and soluble protein (SP) (mg g^{-1} DW) contents of *Hordeum vulgare* plants treated with 0.0, 150, 300 ppm $CdCl_2$ and/or 10% compost, values are mean of three replicates. In each panel: for comparison between stress levels. Values with different letters are significantly different, ($P<0.05$) according to Tukey's test.

4. Effect of $CdCl_2$ and/or banana compost on amino acids and proline contents in barley plants

The data of the contents of the total free amino acid (TAA) and proline (Pr) in *Hordeum vulgare* plants treated with $CdCl_2$ and banana compost are represented in Figure 5. It is clear from the figure that TAA contents increased progressively in both shoot and root organs by increasing cadmium levels.

Treatment of stressed plants with 10 % compost resulted in a significant increase in the content of free amino acids in all levels as compared with corresponding levels of stressed plants. It is worth mentioning that the increase was clear at the highest level in both tested organs as compared with corresponding stressed plants.

Contrary to that, proline content accumulated significantly under various levels of cadmium stresses whether in a shoot or root system. The highest value of proline content at 300 ppm Cd was about 2.05-fold and 1.73-fold of the shoot and root systems, respectively higher than the reference control plants. Data indicated that barley plants when treated with banana compost biofertilizer decreased the accumulation of proline in their shoot and root systems. The reduction of proline in both shoot and root systems of plants treated with biofertilizer reduced by 23.43%, 45.40%, and 51.34% in the case of shoots and 17.13%, 32.76%, and 43.73% in the case of roots as compared with the corresponding level (0.0, 150 and 300ppm $CdCl_2$ levels, respectively).

5. Effect of $CdCl_2$ and/or banana compost on MDA content in barley plants

Figure (6) shows the effect of different treatments ($CdCl_2$ stress and banana compost biofertilizer) on the content of MDA in *Hordeum vulgare* plants. Data indicated that MDA content increased progressively by increasing cadmium stress. The increase in MDA content was proportional to Cd stress levels. Bio fertilization with 10% banana compost leads to a decline in the content of MDA significantly compared with control plants. In *Hordeum vulgare* plants grown on 0.0, 150, and 300ppm $CdCl_2$ and fertilized with banana compost decreased the content of MDA by 3.33%, 26.76% and 25%, respectively in case shoots and 1.45%, 3.45% and 8.28%, respectively in case of roo

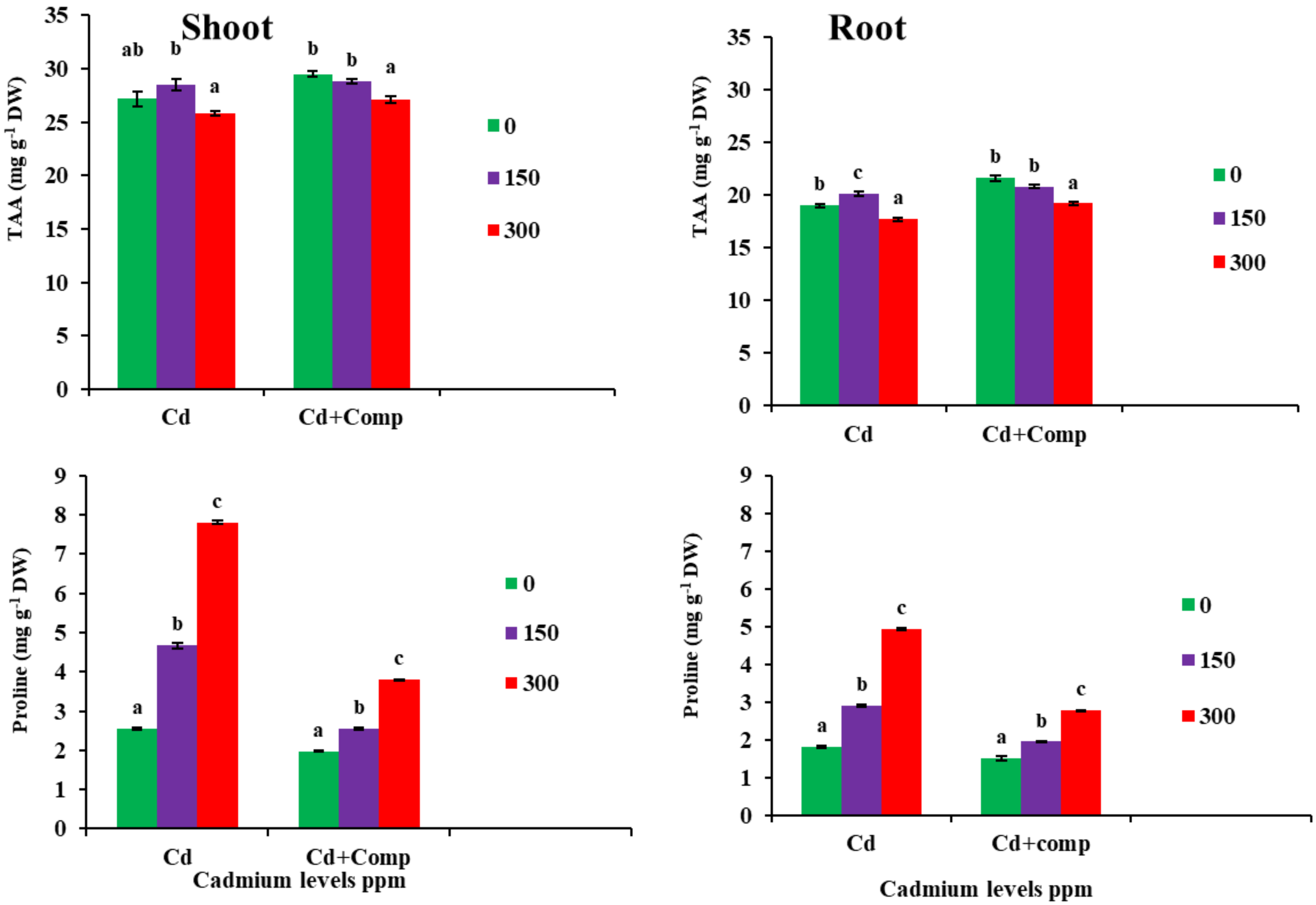

Figure (5): Total free amino acid (TAA) and proline (Pr) (mg g^{-1} DW) contents of *Hordeum vulgare* plants treated with 0.0, 150, 300 ppm $CdCl_2$ and/or 10% compost, values are mean of three replicates. In each panel: for comparison between stress levels. Values with different letters are significantly different (P<0.05) according to Tukey's test.

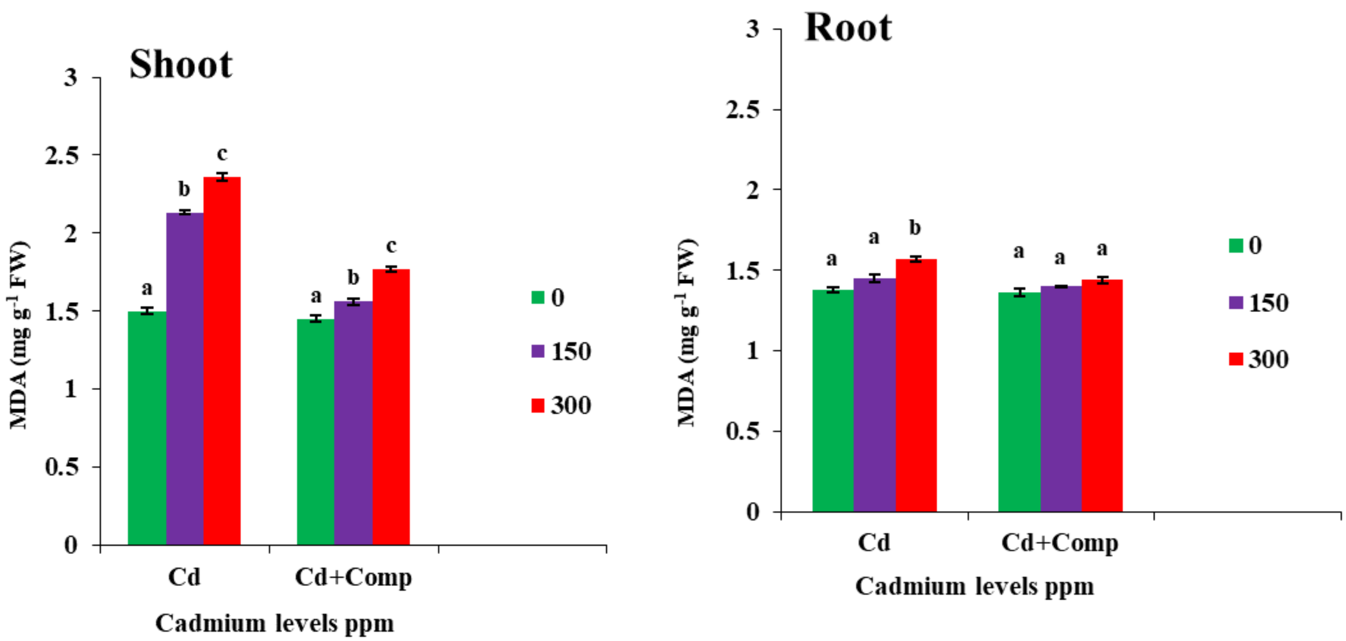

Figure (6): Malondialdehyde (MDA) (mg g^{-1} FW) content of *Hordeum vulgare* plants treated with 0.0, 150, 300 ppm $CdCl_2$ and/or 10% compost, values are mean of three replicates. In each panel: for comparison between stress levels. Values with different letters are significantly different, ($P<0.05$) according to Tukey's test.

6. Effect of $CdCl_2$ and/or banana compost on minerals content and Cd content in barley plants

Figure (7) shows the changes in potassium (K), phosphorus (P) and cadmium (Cd) contents in shoots and roots of *Hordeum vulgare* plants treated with $CdCl_2$ stress and 10% banana compost biofertilizers. It is clear from the figure that K content in the shoot system was higher than in the root system of the experimental plants. The content of K and P in shoot and root tissues decreased significantly by increasing cadmium stress. Application of banana compost stimulated the accumulation of K and P in both shoot and root systems of *Hordeum vulgare* plants, especially at 300 ppm Cd. The accumulation of K and P in the shoot system increased by about 23% and 35%, respectively. While root system recorded about 150% and 22%, respectively as compared with stressed plants.

Cadmium content in shoots and roots of *Hordeum vulgare* plants takes the opposite trend in the case of K and P where it increased by increasing Cd stress levels. However, treatment with banana compost biofertilizer resulted in a marked decrease in Cd contents in both shoot and root organs of the experimental plants as compared with the corresponding unfertilized stress levels.

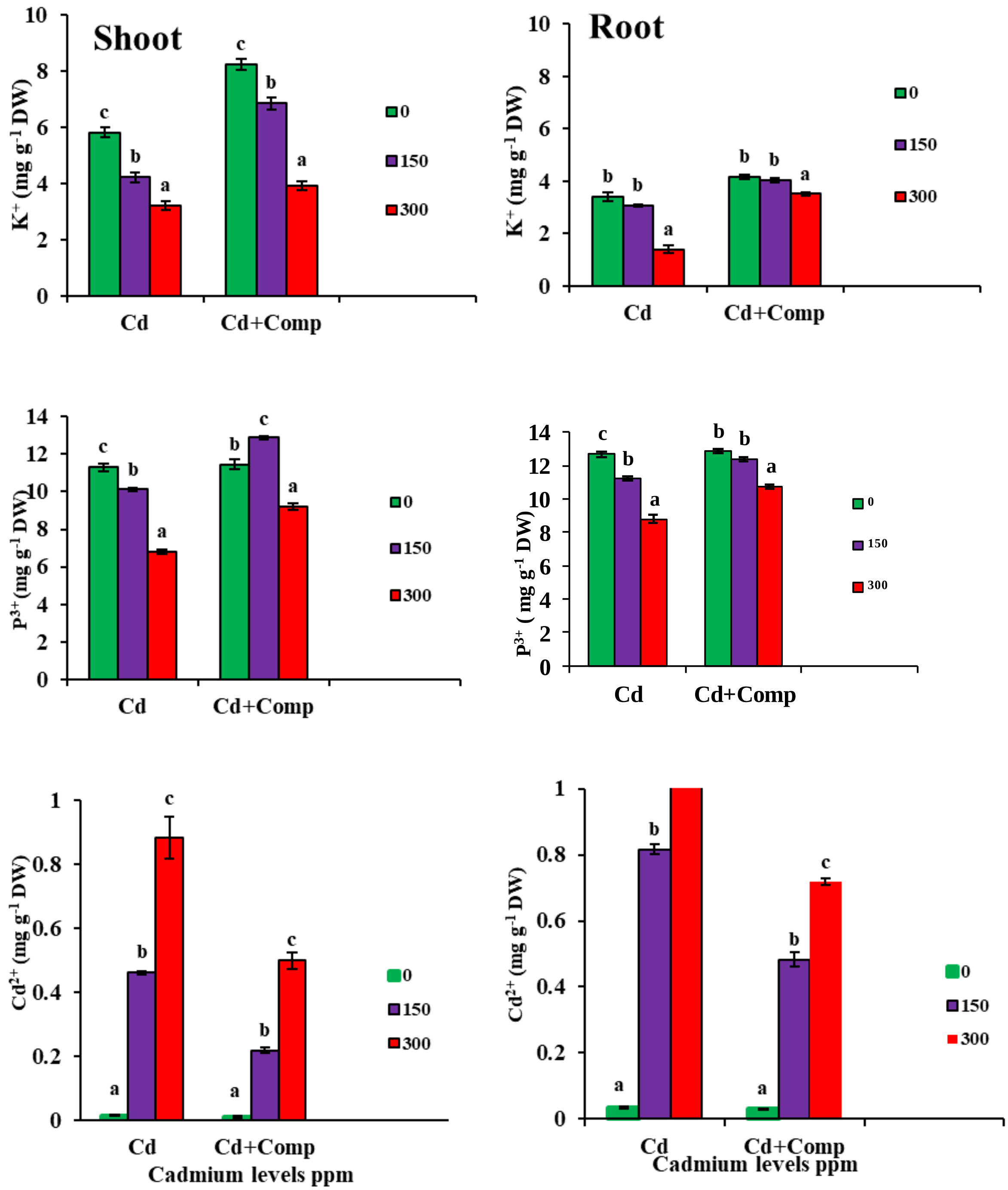

Figure 7: Potassium (**K^+**), phosphorus (**P^{3+}**) and cadmium (**Cd^{2+}**) (mg g^{-1} DW) contents of *Hordeum vulgare* plants treated with 0.0, 150, 300 ppm $CdCl_2$ and/or 10% compost, values are mean of three replicates. In each panel: for comparison between stress levels. Values with different letters are significantly different ($P<0.05$) according to Tukey's test.

DISCUSSION

Cadmium is considered an extremely poisonous heavy metal in the soil and plant nutrition because of its potential harm. Also, it is available in the soil with higher concentrations which induced physiological and morphological damage to plants [41].

In the present study, the toxicity effects of Cd were examined on growth of barley plants. Results revealed that lower concentrations of Cd had a significant impact on the lengths of shoot and root, as well as dry weights. However, with an increase in Cd concentrations, a highly significant reduction in the previous growth criteria was recorded. Earlier studies showed that there is some possibly positive influence of Cd on barley growth at lower concentrations [42]. While the reduction in shoot and root lengths as a result of Cd stress may be due to the competition induced by cadmium with nutrients, causing a mineral disturbance in plants, and as a result their growth becomes slower [43-45]. In a similar experiment carried out on wheat and barley, the effect of Cd on barley and wheat was dependent not only on the concentrations employed but also duration reported by [46]. Moreover, Cd toxicity varies with genotype, duration of exposure, and reduced relative water content in leaves. [47]. The effect of metal shows up very quickly - already after a day of treatment. So, the reduction in the biomass may be attributed to hyperaccumulation of Cd which produces low biomass and delays growth rates [48]. The retardation of dry biomass may be due to the damage that takes place by Cd in the meristematic tissues of the plant, preventing cell development and delaying plant growth particularly in the root system. Root development is more susceptible to the influence of heavy metals than shoot growth. Our findings agreed with [49].

As opposed to that, the application of banana compost improves the negative effect of Cd on both shoot and root lengths because compost having hormone-like activity helps in a greater root initiation and enhanced plant growth [50], increasing soil fertility and crop yield [23]. Also, it may be due to the integration between Cd and organic fertilizers which prevents the availability of Cd [51]. Moreover, it enhanced the overall growth of barley prominently, where it enhanced the fresh and dry biomass of both aboveground and underground parts. This may be owing to its effects on improving the efficiency of organic matter of the soil, increasing nutrient elements, and reducing the toxic effect of Cd on the plant, where all these reasons have a direct action on plant growth reflecting in an enhancement of plant fresh and dry weights. Parallel results were attained by [52] on *Phaseolus vulgaris* and [53] on barley.

The decline in pigment fractions as a result of Cd application in barley leaves may be attributed to the inhibitory effect of Cd on enzymes related with pigment biosynthesis [54] or the adverse effect of toxic Cd in the degradation of chlorophyll a and b [55]. In addition, Cd-induced inhibition in photosynthetic apparatus [56,57]. Similar findings were also reported in other plant species like *Pisum sativum* [58], *Lepidium sativum* [59], *Gossypium hirsutum* [60], *Vicia faba* [61], and *Sassafras tzumu* [10] under Cd-stress conditions.

On the other hand, applications of banana compost resuscitated the growth performance of stressed plants by improving growth attributes and pigment contents (Table 1, figures 2 and 3). The role of compost in the enhancement of pigment content could relate to compost-induced chelation mechanism, reduction in the bioavailability of Cd in soils, degradation of microbes, co-precipitation, and de-methylation [62]. Also, composting helps to stabilize heavy metals from agricultural plants [63] in turn it may reduce the toxic heavy metals' impact taken by plants and recover the degradation in pigment contents and photosynthetic apparatus.

Cd toxicity was found to cause a deleterious effect on plants by disturbing the overall physiological and biochemical plant mechanisms which enhanced the oxidative stress, and to face this stress, plants produced a variety of osmolytes in their cells such as soluble carbohydrates, soluble proteins, free amino acids, and proline [64]. In fact, Cd stress influenced on the water balance in plants and induced an inhibition in carbon metabolism, this inhibition causes a change in photosynthesis because of low CO_2 supply, low carbon levels, reduction in carbon assimilation and reduction in photosynthesis efficiency [65]. The reduction in the content of carbohydrate formation was observed after barley was treated with Cd. Furthermore, the reduction in protein and total free amino acid contents at higher Cd doses in barley may be owing to the inhibition in protein synthesis or the increment in the degradation rate of protein, which was consistent with the results of [66]. Similar results were obtained by [67] where, cadmium doses of

50 and 200 μM in soybean roots caused stimulation in the rates of protease activity. However, higher concentrations of cadmium (200 μM) decreased both protease activity and total protein content. This reflects the toxic effects of higher cadmium concentrations on protein synthesis. In our study, the proline content increased with increasing cadmium concentration, indicating that plants tried to fend off osmotic pressure by increasing the amount of proline. These results are in harmony with the results of [10]. Moreover, the produced reactive oxygen species (ROS) because of oxidative stress may react with lipids, proteins, nucleic acids, and other substances, resulting in lipid peroxidation and membrane damage, so that affecting cell performance and viability [68]. Additionally, MDA content is the indicator of lipid peroxidation in plant cells, which accumulated in the plant cell with exposure to different stresses [69].In this study, the accumulation of MDA might be because of cadmium stress that influences the peroxidation of the cell membranes of barley, causing damage to the structure of the cell membrane.

In contrast, enforcement of banana compost might help to recover the physiological damages induced by cadmium stress. Our findings showed that soluble sugars soluble protein and total free amino acids contents were increased significantly compared to Cd-stressed plants. This enhancement might be due to the ability of organic amendments to increase soil fertility, as they are saturated with carbon, hydrogen, and oxygen [70]. Thereby, a modification in physical and chemical characteristics of soil, organic matter, and different nutrients resulted in increasing growth and yield, this could improve the contents of osmoprotectants in the plant cells [71,72]. Besides, the application of bio-fertilizers like compost, it was found to increase the availability of both macro-and micronutrients to plants, where it plays an important role in metabolic activities including proteins and sugars synthesis [73]. However, the amount of proline and MDA accumulation was significantly reduced, indicating that compost treatments can reduce the severity of Cd-induced osmotic imbalance in barley plants. The reduction in proline and MDA contents after compost application may be referred to as the ability of compost to alleviate the oxidative stress induced by metal stress. These findings agreed with the results of [74,75]. Our results indicated that Cd deposition in barley destroyed the balance of mineral homeostasis. Cd stress decreased K^+ and P^{3+} contents in all plant parts, because of excessive accumulation of Cd^{2+} in the shoot and root. With the increased absorption rate of Cd^{2+} ions, a significant decline in other ions (e.g., K^+ and $P^{3+)}$ was exhibited in previous studies [76-78]. Cadmium was found to interact with the use, storage, and utilization of several elements (i.e., Ca, Mg, P, and K) [79]. In addition, it competes with the essential nutrients which hinder the transportation of macro and micronutrients [80].

Unlike Cd, compost organic amendment reestablished ionic balance by decreasing uptake of Cd^{2+} along with stimulating the K^+ and P^{3+} levels in barley. These above-mentioned results indicated that banana compost may induce chelation, adsorption, and precipitation of soil Cd [69,81]. Similar results were ensured in our findings where the application of compost in maize plants reduced Cd concentration in shoots and roots and significant increase in and NPK contents [82]. Also, the usage of compost decreased the concentration of cadmium of pak choi cabbage in both roots and shoots in contaminated soils with heavy metals [83].

CONCLUSION

Our results confirmed that the barley plant endured the toxic effect of Cd and relatively tolerate Cd at a mild level due to the roots which act as a physiologically active protection barrier restricting the translocation of Cd to the shoot system. Also, the applications of banana compost on Cd-stressed barley plants successfully alleviated stress-induced effects on the experimental plants. The banana compost amendment considers one way to achieve rapid results, recovers soil health, chemical, and physical properties, natural and environmentally friendly fertilizers, increase the income of the farmers, and reduced the cost of using chemical fertilizer.

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