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Effect of *Padina pavonica* on nutrient contents of *Zea mays L*. grown under cadmium or nickel stress.

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ABSTRACT

The aim of this study was to test the potential of the brown marine macroalgae, *Padina pavonia* for reducing the growth inhibition of *Zea mays* L. induced under 100 µM Cd+2 or 150 µM Ni+2 stresses. The impact of *Padina pavonia* was studied comparing to two well-known plant growth modulators; ascorbic acid and cysteine. Cadmium treated roots showed a significant decrease in Ca+2, Fe+2, Na+ and Zn+2 contents while an increase in Pb+2 content compared to control roots. However, shoots treated with Cd+2 accumulated Fe+2 and Pb+2 while induced a decrease in Cu+2 and Zn+2 contents. For Cd+2 treated roots: cysteine was the most effective modulator for Ca+2 and Fe+2 while *Padina pavonica* was for Na+ and Pb+2 whereas ascorbic acid was the most effective one for recovering Ca+2, Pb+2 and Zn+2 contents in maize shoots. Roots treated with Ni+2 showed a significant decrease in Ca+2, Cu+2, Fe+2 and Na+ contents while an increase in Pb+2 and Zn+2 contents compared to control roots. However, shoots treated with Ni+2 accumulated Cu+2 while induced a decrease in Ca+2, Fe+2, Na+, Pb+2 and Zn+2 contents. In addition, cysteine was the effector for the recovery of Fe+2, Na+ and Pb+2 concentrations in Ni+2 treated roots and Na+ and Zn+2 in Ni+2 treated shoots. For *Padina pavonica*, it recovered Ca+2, Pb+2 effectively in Ni+2 treated shoots only. For ascorbic acid, it recovered: Cu+2 roots and shoots, Ca+2 roots and Fe+2 shoots. We conclude that *Padina pavonica* is an effective bioremediator for Cd+2 and Ni+2 stresses.

Keywords: Bioremediation, *Padina pavonica*, Heavy metals stress, *Zea mays* L.

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INTRODUCTION

Plants have a remarkable ability to take up and accumulate trace metal elements from their external. Heavy metals such as Cd+2, Pb+2, Hg+2, Cu+2, Zn+2, and Ni+2 at supra-optimal concentrations affect plants growth, development and yield [1,2,3]. Human activities such as mining, industrial production, transport and agriculture release ever-increasing amounts of bioavailable trace metal elements into the environment. Plants grown on contaminated soils may have reduced productivity and uptake of trace elements by plant may facilitate the entry of toxic elements into the food chain, possibly affecting human nutrition. Accumulation of heavy metals may result in contaminant doses that could have deleterious consequences. Some metals and metalloids are known carcinogens and can reduce mental and nervous system function, cause lower energy levels, damage vital organs [4], and cause DNA damage [5].

Heavy metals are able to interact with essential macro- and microelements, thus exerting a significant influence on plant nutrient uptake. Cadmium was reported to reduce the uptake of iron [6] and of nitrogen, phosphorus, potassium, zinc, copper, and sodium [7]. There are a number of reports showing that Ni+2 is an active competitor of a number of essential nutrients such as Mg+2, Mn+2, Fe+2, Zn+2 and Ca+2 [8,9] Phytoremediation has emerged as a practical approach to clean up metal polluted soils. In this study, the role of the brown algae; *Padina pavonica* as a potential phytoremediator to soils contaminated with cadmium (Cd+2) and nickel (Ni+2) was investigated in *Zea mays* L. plants.

MATERIALS AND METHODS

Treatments:

Grains of maize (*Zea mays* L. var. Yellow, 325) were obtained from Research Station, Giza, Egypt. To test viability of maize grains, germination percentage was estimated (90%). Maize grains were sterilized and germinated in 30 cm depth and 30 cm diameter pots filled with sandy soil and all pots were irrigated with water for 7 days. To study the effect of some growth modulators on the growth inhibition induced under 100 µm Cd+2 or150 µm Ni+2 treatments, cysteine (0.1 or 0.5 mM) and ascorbic acid (2 mM or 5 mM) were applied in irrigation water. The brown algae *Padina pavonica* were freshly collected manually from Salman Bay of the Red Sea; Jeddah, KSA in April 2012. Algae washed with seawater to remove all the unwanted impurities such as adhering sand particles and epiphytes and transported in plastic bags according to the steps described by [10]. Thereafter, algae were dried at room temperature away from light and then ground in the form of powdered particles ready for use. Different concentrations of *Padina pavonica* (2%, 3.33% or 4.66%) were added to the soil, mixed well before cultivating maize grains. Each experiment was set up as randomized complete block with 3 replicates each containing a raw of each treatment.

Estimation of mineral contents

Plants treated with different treatments were divided into roots and shoots. Plant samples were dried at 45ºC in an oven for a one week period or until no further reduction in weight occurred. To determine exchangeable cations (Ca+2, Cu+2, Fe+2, Na+2, pb+2, Zn+2), one half g of oven dried plant samples was digested with 6.5 ml nitric acid (70% Trace Metal Analysis, TMA) using a 15 min ramp program set to a power maximum of 1200 W and held for 15 min. The samples were allowed to cool to room temperature and transferred to 50 ml volumetric flasks. Solutions of soil and plant tissue samples were then analyzed for the cations previously mentioned using an inductively coupled plasma atomic emission spectrometer (ICP-OES) using IRIS Intrepid II XSP instrument. Sixpoint calibration procedure was applied with multielement calibration solution (Merck ICP multi-element standard solution).

RESULTS

Application of 100 µM Cd^{+2} or 150 µM Ni^{+2} altered the nutrient contents of maize roots and shoots as indicated in (Figs. 1-12). Cadmium treated roots showed a significant decrease in Ca^{+2}, Fe^{+2}, Na^{+} and Zn^{+2} contents while an increase in Pb^{+2} content compared to control roots. However, shoots treated with Cd^{+2} accumulated Fe^{+2} and Pb^{+2} while induced a decrease in Cu^{+2} and Zn^{+2} contents. Roots treated with Ni^{+2} showed a significant decrease in Ca^{+2}, Cu^{+2}, Fe^{+2} and Na^{+} contents while an increase in Pb^{+2} and Zn^{+2} contents compared to control roots. Moreover, shoots treated with Ni^{+2} accumulated Cu^{+2} while induced a decrease in Ca^{+2}, Fe^{+2}, Na^{+}, Pb^{+2} and Zn^{+2} contents.

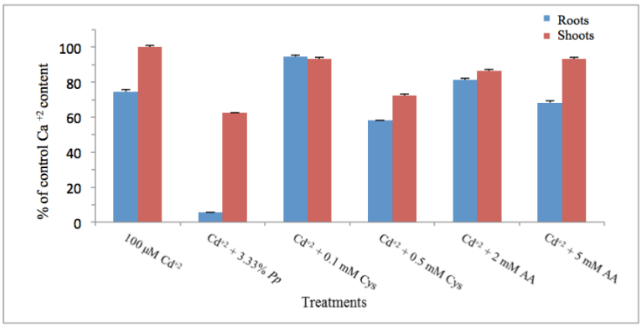

Figure 1: Effect of 100 µM Cd^{+2} in presence of either *Padina pavonica* (*Pp*) or different concentrations of cysteine (Cys) or ascorbic acid (AA) on Ca^{+2} (mg/100g dry weight) content of 37-day old *Zea mays* L. roots and shoots.

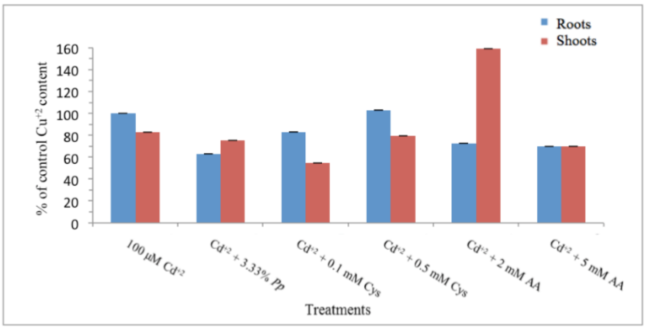

Figure 5: Effect of 100 µM Cd^{+2} in presence of either *Padina pavonica* (*Pp*) or different concentrations of cysteine (Cys) or ascorbic acid (AA) on Cu^{+2} (mg/100g dry weight) content of 37-day old *Zea mays* L. roots and shoots.

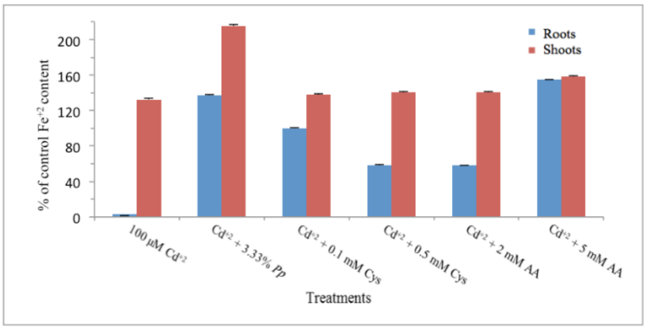

Figure 3: Effect of 100 µM Cd^{+2} in presence of either *Padina pavonica* (*Pp*) or different concentrations of cysteine (Cys) or ascorbic acid (AA) on Fe^{+2} (mg/100g dry weight) content of 37-day old *Zea mays* L. roots and shoots.

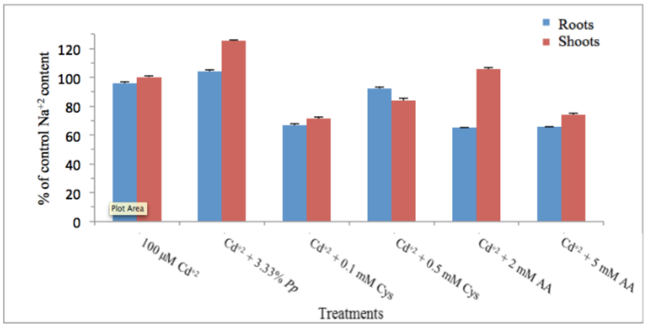

Figure 4: Effect of 100 µM Cd^{+2} in presence of either *Padina pavonica* (*Pp*) or different concentrations of cysteine (Cys) or ascorbic acid (AA) on Na^{+2} (mg/100g dry weight) content of 37-day old *Zea mays* L. roots and shoots.

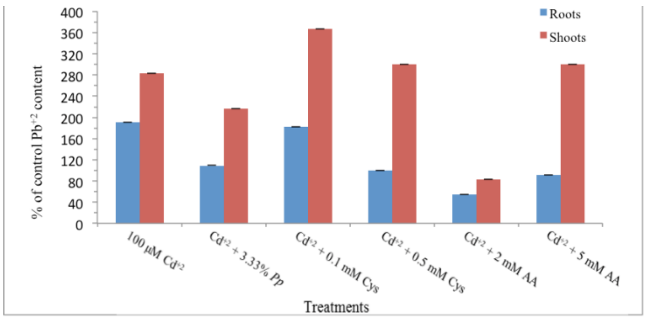

Figure 2: Effect of 100 µM Cd^{+2} in presence of either *Padina pavonica* (*Pp*) or different concentrations of cysteine (Cys) or ascorbic acid (AA) on Pb^{+2} (mg/100g dry weight) content of 37-day old *Zea mays* L. roots and shoots.

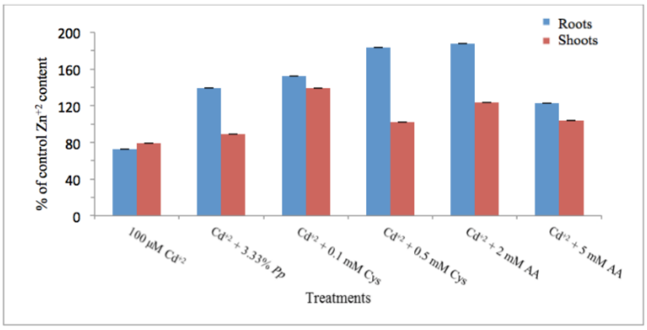

Figure 6: Effect of 100 µM Cd^{+2} in presence of either *Padina pavonica* (*Pp*) or different concentrations of cysteine (Cys) or ascorbic acid (AA) on Zn^{+2} (mg/100g dry weight) content of 37-day old *Zea mays* L. roots and shoots.

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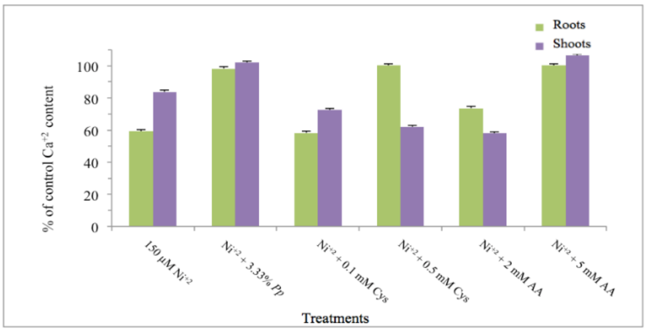

Figure 7: Effect of 150 µM Ni^{+2} in presence of either Padina pavonica (Pp) or different concentrations of cysteine (Cys) or ascorbic acid (AA) on Ca^{+2} (mg/100g dry weight) content of 37-day old Zea mays L. roots and shoots.

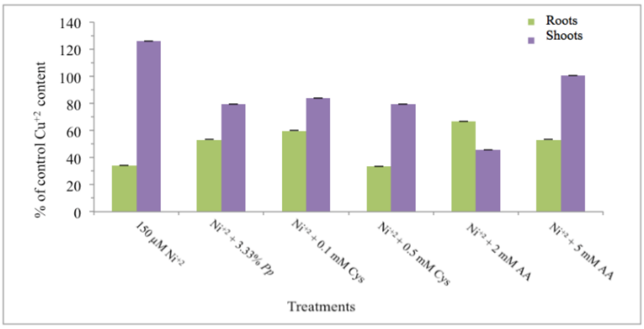

Figure 8: Effect of 150 µM Ni^{+2} in presence of either Padina pavonica (Pp) or different concentrations of cysteine (Cys) or ascorbic acid (AA) on Cu^{+2} (mg/100g dry weight) content of 37-day old Zea mays L. roots and shoots.

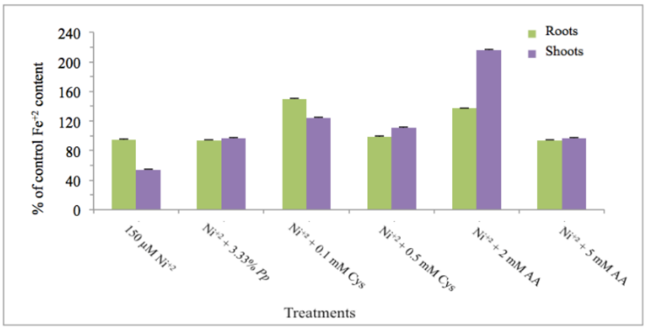

Figure 9: Effect of 150 µM Ni^{+2} in presence of either *Padina pavonica* (*Pp*) or different concentrations of cysteine (Cys) or ascorbic acid (AA) on Fe^{+2} (mg/100g dry weight) content of 37-day old *Zea mays* L. roots and shoots.

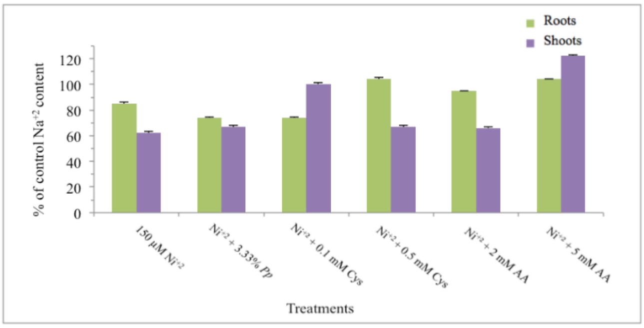

Figure 10: Effect of 150 µM Ni^{+2} in presence of either *Padina pavonica* (*Pp*) or different concentrations of cysteine (Cys) or ascorbic acid (AA) on Na^{+2} (mg/100g dry weight) content of 37-day old *Zea mays* L. roots and shoots.

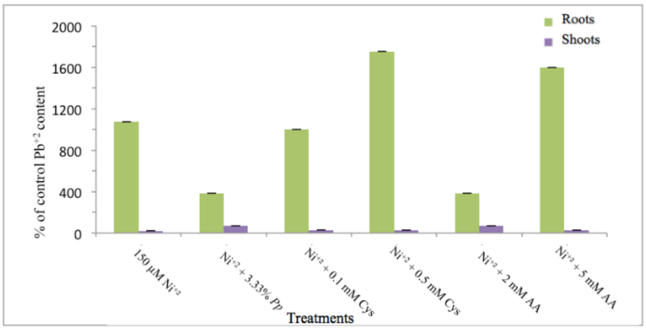

Figure 11: Effect of 150 µM Ni^{+2} in presence of either *Padina pavonica* (*Pp*) or different concentrations of cysteine (Cys) or ascorbic acid (AA) on Pb^{+2} (mg/100g dry weight) content of 37-day old *Zea mays* L. roots and shoots.

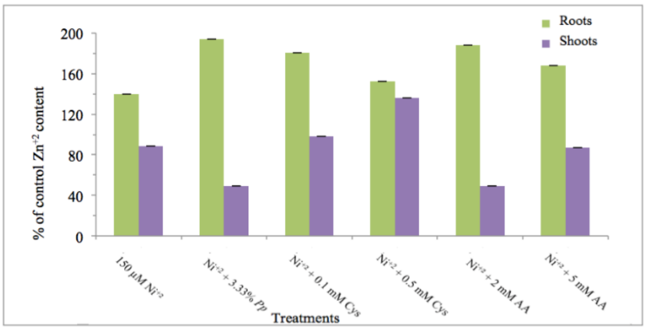

Figure 12: Effect of 150 µM Ni^{+2} in presence of either *Padina pavonica* (*Pp*) or different concentrations of cysteine (Cys) or ascorbic acid (AA) on Zn^{+2} (mg/100g dry weight) content of 37-day old *Zea mays* L. roots and shoots.

In Cd^{+2} treated roots, cysteine was the most effective modulator for Ca^{+2} and Fe^{+2} while *Padina pavonica* was for Na^{+} and Pb^{+2} whereas ascorbic acid was the most effective one for recovering Ca^{+2}, Pb^{+2} and Zn^{+2} content in maize shoots. For Ni^{+2} treated roots and shoots, all the three modulators showed almost the same trend.

Statistical analysis showed that the effects of either *Padina pavonica* or different concentrations of cysteine or ascorbic acid in presence of 100 µM Cd^{+2} or 150 µM Ni^{+2} were highly significant ($P<0.001$) on mineral contents of plant roots and shoots compared to control.

DISCUSSION

Our results contained in (Figs. 1-12) showed that presence of Cd+2 or Ni+2 altered the contents and distribution of all the tested mineral nutrients (Ca+2, Cu+2, Fe+2, Na+, Pb+2 and Zn+2) in *Zea mays* L. roots and shoots. At a physiological level, roots and shoots of Cd+2 or Ni+2 treated plants showed a deficiency of the contents of all the tested nutrients except Pb+2 as it was accumulated in both tissues. This remarkable observation is agreed with data found in lots of published papers. Excess soil heavy metals including divalent cations such as Cd+2 and Ni+2 get enriched excessively through non-specificity of transporters and channels that led to uptake and transport the essential minerals. Generally, heavy metals may interfere with the uptake and transport of other essential nutrients and thereby disturb the status of mineral nutrients in plants [11].

Therefore, nutrient deficiencies under metal stressed condition results in an altered growth pattern of seedling of agricultural crops that result in poor crop establishment in later stages of crop development [12] and [13]. In particular, Cd+2 uptake occurs through transmembrane carriers engaged in the uptake of Ca+2, Fe+2, Mg+2, Cu+2 and Zn+2 [14] and [15].

Nickel competes for uptake and translocation with other essential nutrients in plants and may reduce their concentration to deficiency level. Therefore, the concentration of other essential metals such as Fe+2, Cu+2, Zn+2, Mg+2, Fe+2 and Mn+2 decreases under nickel stress [16] and [17]. It has been shown that copper toxicity has a significant effect on enzyme production and metabolism.

Since the nutrients are involved in a number of physiological processes, their deficiency in plants may retard a number of metabolic processes [18] and [19]. Subsequently, it may result in the suppression of growth and development as well as reduction in yield of agricultural crops [3] and [20].

However, all the alterations of the contents and distributions of the above mentioned metal contents estimated in Cd+2 and Ni+2 treated plants were rearranged differently in presence of either *Padina pavonica* or cysteine or ascorbic acid as clearly observed in (Fig. 1-12).

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