



**ASSESSING THE BIOACCUMULATION OF ELEMENTS IN TWO ARID-
REGION PLANTS UNDER THE INFLUENCE OF ELECTRIC FIELDS IN
JEDDAH PROVINCE, KINGDOM OF SAUDI ARABIA**

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ABSTRACT

To investigate the impact of electric power on the bioaccumulation of elements of the two most prevalent plants in the region, *Prosopis laevigata* (*P. laevigata*) and *Calotropis gigantea* (*C. gigantea*), the Al-Shuaiba Power and Desalination Plant in Jeddah province was chosen. A site close to the power plant (referred to as the affected area) and another site far from the electric power plant (referred to as the unaffected area) were chosen in order to examine this effect. Each selected location covers an area of 100 m² (10m× 10m). Macro-elements, microelements and heavy elements were estimated in term of Mg/Kg for both plants in the two locations. Results revealed that, the electric field reduced the amount of macro elements, in terms of Na, Ca, Mg, and N. Nonetheless, the concentration of some harmful heavy elements, such as Al and Ba, was reduced as well. However, the response of plants was not the same; *C.gigantea* seems to be more effective in obtaining reasonable macronutrient and reducing harmful heavy elements compared to *P.laevigata*. More research is needed into plant physiology and biochemistry under electric fields.

Keywords: electric field, electric power plant, Al-Shuaiba, *Calotropis gigantea*, *Prosopis laevigata*

1. INTRODUCTION

The Kingdom of Saudi Arabia is a sizable nation with a variety of climates. It has large deserts, rough mountains, cities, villages, and towns along the shore. The nation's usage of electricity is rising quickly. Saudi Electricity Company generated 198,900 GWH of electricity in 2013. [1]. By the year 2020, it is intended to boost the electricity grid's capacity by 120 gigawatts. Overhead power transmission lines are typically used to transport electricity produced by power plants across great distances. This nation's local substations are served by an interconnected infrastructure of high-voltage electricity transmission cables that travel atop towering towers.

The high transmission voltage of 380 kV may affect the adjacent plants' growth. Some authors showed that electric fields (EF) could positively influence seed germination and plant growth rates by increasing free water content, metabolic enzyme activity, and membrane permeability, which helps break dormancy and improve seed vigour. However, they concluded that, the effect is dependent on the specific plant species, the type and strength of the electric field, and exposure time, as overly strong or prolonged exposure can have negative impacts, [2-6]. In contrast to these findings, a body of research indicates that electric fields can suppress seed germination and hinder plant growth. The negative effects, such as

reduced seedling development, appear primarily with high-intensity or static fields, though outcomes are highly variable depending on the plant species and the specifics of the field's intensity and duration. The exact effects vary depending on the field's characteristics and can be contradictory, with some studies reporting increased growth and germination and others reporting suppression [7-9]. According to some authors, electromagnetic fields (EMF) create an oxidative stress that raises the levels, longevity, and activity of free radicals [10]. In addition, researchers found that, the effects of electric fields on various plants vary depending on the variety of plants [11, 12]. Regarding the result obtained by [13], when palm seedlings were exposed to various magnetic fields for various lengths of time, concentrations of Ca, Mg, Mn, Fe, Na, K, and Zn increased in palm leaves. Moreover, [14, 15] on their studies finalized that, an electric field is likely to enhance development since it has a good impact on the plant's key elements like Ca and Mg, but it inhibits the uptake of K and P. However, further research is needed on the impact of electric fields on plants' mineral and heavy element composition.

1.1.AL-Shuaiba power and desalination plant:

Around 120 kilometres (75 miles) south of Jeddah in Saudi Arabia, on the Red Sea

coast, is the oil-fired, combined cycle gas turbine power and desalination complex known as Al-Shuaiba (Coordinates: 20.680084°N 39.523233°E). It is the third-biggest combined water and power plant and one of the largest fossil fuel power stations in the world. The generators are

connected to a bigger, 380 kV power grid. There is 380kV of electricity between each wire transmission tower. Saudi Arabia's power and water ministry monitors the Shoaiba power station, Saline Water Conversion Corporation.



AL-Shuaiba power and desalination plant

1.2. The species under study:

1.2.1. *Calotropis gigantea*

(family *Apocynaceae*, subfamily *Asclepiadaceae*), The *Calotropis* species known as the "crown flower" is indigenous to Bangladesh, Cambodia, Vietnam, Indonesia, Malaysia, Thailand, Sri Lanka, India, China, Pakistan, and Nepal. The leaves of *C. gigantea* are used to treat fevers that come and go, swellings, and paralysis. In addition to Asthma, catarrh, anorexia, helminthic infections, inflammations, and

fever can all be treated with the flowers of this plant. The plant's root bark is utilized for ascites, intestinal worms, helminth infections, and skin infections [16]. The plant has milky stems and round, light green leaves. The latex of the *Calotropis gigantea* plant contains cardiac glycosides, fatty acids, and calcium oxalate. These chemicals are known to be bioactive, and they have been the focus of numerous scientific studies into the plant's chemical composition and medicinal potential [17, 18].



Calotropis gigantea, during flowering and fruiting

1.2.2. *Prosopis laevigata*

Native to Mexico, Bolivia, Peru, and northwest Argentina, smooth mesquite is a species of flowering tree in the Fabaceae family of peas. It grows in a number of locations, including hillsides, depressions, and floodplains. It has also been seen to

grow in the Middle East. A native tree with 44 species found in arid and semiarid regions covering one-third of the earth's surface, mesquite (*Prosopis* spp.) is a member of the Leguminosae family and the Mimosaceae subfamily [19-21], described the antioxidant activity of *P. laevigata*.



Prosopis laevigata, during fruiting

1.3. Objectives of the study:

The overall aim of this study is to identify and characterize alterations in plant elemental content induced by exposure to high-voltage transmission line electric fields. Furthermore, the specific objectives encompass assessing the differential bioaccumulation of macro-, micro-, and heavy metal elements in the foliage of exposed plants versus control samples to establish a metric of environmental impact

2. MATERIALS AND METHODS:

2.1. Area Selection:

To investigate the influence of the electric field on plants, Al-Shuaiba Power and Desalination Plant in Jeddah province was selected to study the effect of the electric power on most dominant plants in the area, namely, *Prosopis laevigata* (*P.laevigata*) and *Calotropis gigantea* (*C.gigantea*)

growing in the area of the electric plant (referred to as affected area). In addition, another location far away from the electric power plant was chosen as control where the two plants are found (referred to as unaffected area). Each selected location covers an area of 100 m (10m× 10m). Macro-elements, microelements and heavy elements were estimated in term of Mg/Kg for both plants in the two locations.

2.2. Field and Laboratory Experiments:

This study was performed in two parts, the first part was field study which include field study to select the plant species and define the distances of the species from the electric field in both sites. Fresh leaves of the two plants (*Calotropis* and *Prosopis*) were collected from each site (10 leaves from each plant in 3 replicates). The second phase of the study was conducted in the laboratory

to quantify the essential and heavy elements in both plants from the two locations, including macro elements (N, K, Na, Ca, Mg), microelements (Cu, Fe, Mn, Zn), and toxic heavy elements (Ba, Pb, Ti, V, Cr, Ga, Ni, Al).

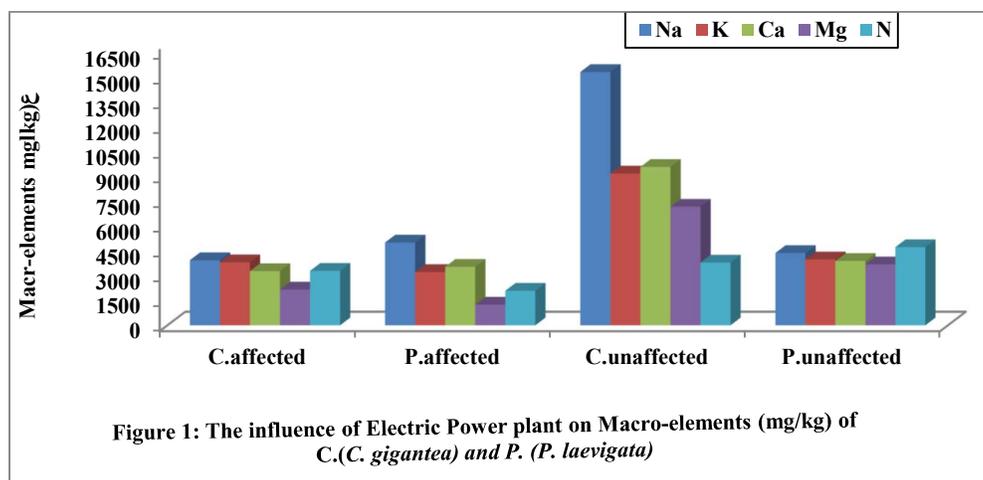
2.3. Determination of Elements in Plant Samples

After the leaves were allowed to air dry in the lab, Retake *et al.* technique [22] was applied. The digesting containers were filled with a plant sample that weighed 0.5 g (dry bulk). Next, five millilitres of concentrated HNO₃ and one millilitre of 30% H₂O₂ were added to each sample. For sixteen hours, the samples were pre-digested at room temperature in a fume hood. The plant samples were digested in accordance with the following ideal program (power in W / time in min). The internal temperature was limited to 240°C in the last stage. After chilling, the entire digest was poured into 60 ml plastic bottles, and the volume was diluted to 50 g using double-deionized water. Reagent blanks were made in the same manner as the samples. The entire sample solution was made clear and diluted ten times prior to analysis. Heavy metal concentrations in plant samples were determined. Atomic absorption spectrometry (AAS) analysis.

3. RESULTS

3.1. Macro-elements:

Figure 1 illustrates the different effects of the electric field on both sides of the plant. In the affected area, both plants showed lower amounts of Na, K, Ca, and N elements compared to plants in the unaffected area. *C.gigantea* had almost similar amounts of Na, K, and Ca (3940, 3815, 3280, and 3295 mg/kg), respectively. The amount of magnesium was the least (2160 mg/kg). In contrast, *P. laevigata* elements in the same area contained almost twice as much sodium (5010 mg/kg) as *C. gigantea*. Results of K and Ca showed no significant difference in *P. laevigata* compared to those of *C.gigantea*. As a point of interest, affected *P. laevigata* contain less Mg (1250 and 2090, respectively) than unaffected *P. laevigata*. Comparing to plants at unaffected area, all nutrients showed a pronounced high amounts especially in *C. gigantea*. Na was increased by 4 times than at the affected area (significant at $P < 0.01$ (15315 mg/kg), followed by Ca (9578 mg/kg), K (9180 mg/kg), Mg (7170 mg/kg) and N (3795 mg/kg). Conversely, *P. laevigata* leaves showed almost less than half amount than those of *C. gigantea* in terms of Na, K, Ca and Mg, Nonetheless, Ni was high (4725 mg/kg) compared to (3795mg/kg) in *C gigantea* at the same area.



3.2. Micro-elements:

The microelement levels of both plants at the two locations in terms of Cu, Fe, Mn, and Zn are shown in **Figure 2 and 2a**. Concerning Cu, Mn and Zn, the amounts recorded for these elements showed wide variations between the two species at the two areas (**Figure 2**). Cu of *C. gigantea* at the affected area was double the amount at the unaffected area (14.5 mg/kg, 7.50 mg/kg, sig at $P. \leq 0.01$) respectively. While in *P. laevigata* there was no significant difference between affected and unaffected plants (20.5 mg/kg, 24.0 mg/kg) respectively. Both plants showed a substantial difference in Mn concentration between unaffected and affected areas. In the unaffected area, *C. gigantea* had 150.7 mg/kg compared to *P. laevigata* (110 mg/kg). In the affected area, *C. gigantea* was 81.5 mg/kg versus 68 mg/kg for *P. laevigata*. Zn, on the other hand, had the lowest value in *C. gigantea* at the affected area (41.4 mg/kg), and the highest

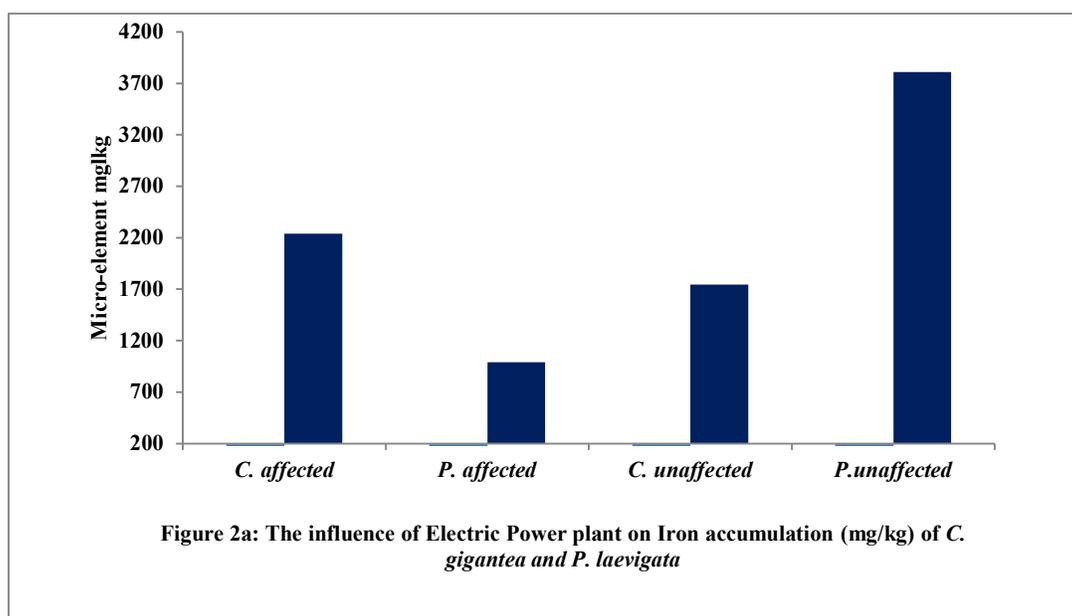
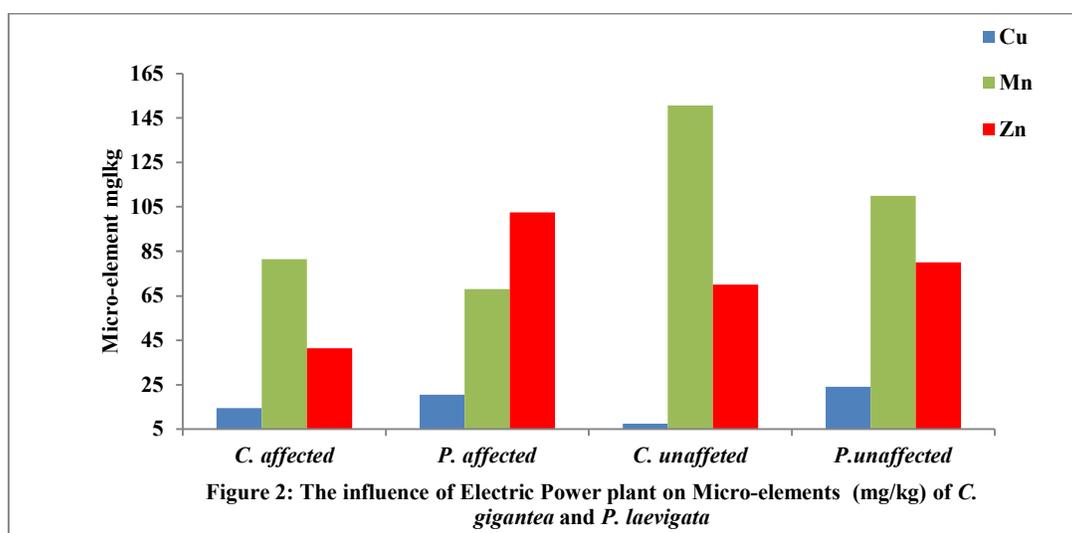
value was recorded in *P. laevigata* at the affected area (102.5 mg/kg, significant at $P \leq 0.01$). Notably, Zinc (Zn) levels in the unaffected area were comparable between the two plants (70 mg/kg in *C. gigantea* versus 80 mg/kg in *P. laevigata*). Iron (Fe) concentrations, however, showed a stark contrast between regions and species. In the unaffected area, *P. laevigata* had nearly twice the iron (3808 mg/kg) compared to *C. gigantea* (1743 mg/kg, sig at $P. \leq 0.01$). Conversely, *C. gigantea* showed a higher iron accumulation in the affected area (2240 mg/kg versus 990 mg/kg in *P. laevigata*, sig at $P. \leq 0.01$) (**Figure 2a**).

3.3. Heavy elements:

The effects of electric power on the concentrations of heavy elements (Ba, Pb, V, Cr, Ga, Ni, and Al) in the leaves of *C. gigantea* and *P. laevigata* are represented in Figures 3 and 3a. *P. laevigata* showed a distinct sequence: Al>Pb>Ni>Ba>V>Cr>Ga, but *C. gigantea* showed the following order of element

concentration in the afflicted area: Al>Ba>Cr>V>Ni>Pb>Ga. Noteworthy, at the affected area, *P. laevigata* showed significantly high Pb amount (23.2 mg/kg, compared to 6.0 mg/kg, of *C. gigantea*, $P<0.01$). A similar outcome was observed in the case of Ni. The leaves of *C. gigantea* accumulated 6.5 mg/kg of Ni, whereas *P. laevigata* leaves accumulated 23 mg/kg $P<0.01$, in the affected area. At the

unaffected area however, *P. laevigata* accumulated 12.0 mg/kg, while *C. gigantea* leaves accumulated 7 mg/kg. Regarding the amount of Ba accumulation in the leaves of the two plants, *P. laevigata* had lower amount than that of *C. gigantea* (19.95 mg/kg and 29.35 mg/kg, respectively). The two plants in the affected area had the same level of gallium (Ga) (0.5 mg/kg).



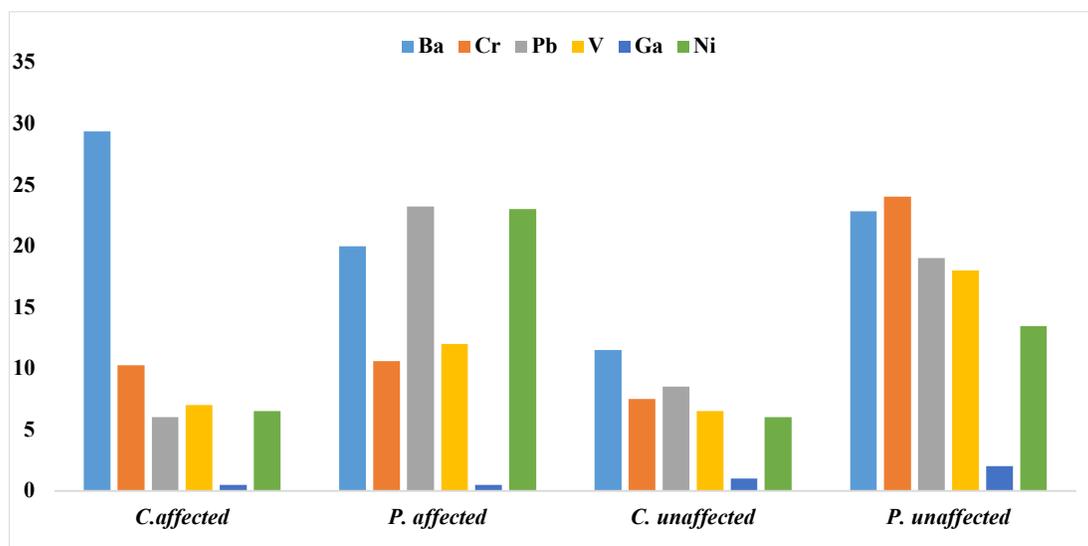


Figure 3: The influence of electric power plant on heavy elements (mg/kg) of *C. gigantea* and *P. laevigata*

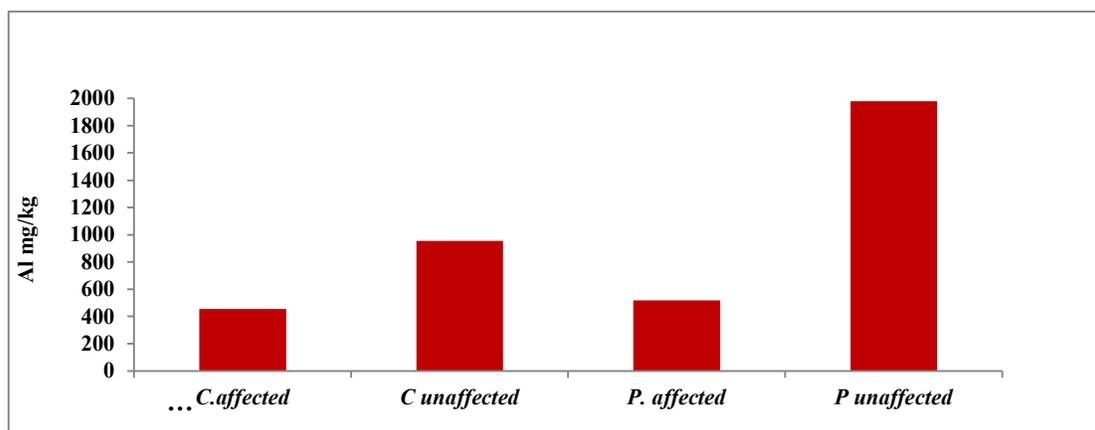


Figure 3a: The influence of electric power plant on Aluminium (AL) (mg/kg) of *C. gigantea* and *P. laevigata*

The same insignificant result was observed Cr. (10.27mg/kg in *C. gigantea* compared to 10.6mg/kg in *P. laevigata*). Aluminium (Al.) values (Figure 3a) was the highest among all other elements but there was no significant difference between the two species at the affected area (455 mg/kg in *C. gigantea* compared to 520 mg/kg). At the unaffected area, Al. still had the highest value among other elements. The value of Al in *P. laevigata* was double that in *C.*

gigantea (1980 mg/kg compared to 955 mg/kg, significant at $P < 0.01$).

4. DISCUSSION

The electric field decreased the accumulation of macro elements in both species, according to the results. *C. gigantea* had high levels of Na, K, Ca, Mg, and N, but *P. laevigata* had much lower levels of all elements except Na. This is in line with the findings of Hanafy *et al.*, [15], who discovered that the breakdown of the plasma membrane caused a decrease in element

content in exposed wheat grains, particularly K. In the unaffected area, the amount of sodium in *C. gigantea* leaves was found to be high. In addition, [23] reported comparable findings in *Zea mays* L., however, these findings differ from those of Alaish [24], who observed a significant salt concentration in the vicinity of the electric field. Both plants in the two areas accumulated high amounts of iron, as indicated by the microelements results. According to some authors, Alaish [24], this may be due to soil acidity. The findings of this study provide a rationale for further research on the biological effects of electricity on trace metals in plants. Electric field cause an increase in Cu and Mn and a decrease in Zn but only in *C. gigantea*. This is because Cu and Mn tend to accumulate near positive charge accumulations or participate in polarization processes; an electric field increases Cu and Mn in a system. In contrast, it decreases Zn by causing electrostatic repulsion from negatively charged regions, leading to migration and deposition in areas away from the negative pole of the field or hindering Zn deposition due to repulsion forces [25]. Moreover, electric field reduced Al accumulation to almost half the amount in both plants compared to plants at unaffected area. The beneficial effect of Al in plants has been reported mainly in woody species adapted to acid soils [26]. Some plants, such

as barley, rice, and cowpea, can exhibit a reduced accumulation of manganese (Mn) when aluminium (Al) is present, thereby alleviating Mn toxicity. Al can decrease Mn uptake and root tissue concentration by affecting the electrical potential on root cell membranes or through direct competition for uptake. This antagonistic interaction between Al and Mn helps to reduce the detrimental effects of Mn toxicity, particularly in acidic soils where both metals can be abundant [27-30]. However, Aluminium is widely reported as toxic to most plants [31]. On the other hand, Ba was increased under electric field especially in *C. gigantea*. Barium (Ba) is a nonessential element to terrestrial plants and is known to be toxic at elevated concentrations. Elevated Barium (Ba) concentrations can be toxic for plants and may affect growth and disturbances in homeostasis [32, 33]. This may count as an adverse effect of electric field on plants. However, the two-plant respond differently in case of Ba, *P. laevigata* had less Ba values than *C. gigantea*.

5. CONCLUSION:

According to this study, exposure to electric fields can decrease some harmful heavy metals, but it may also decrease essential elements, as observed in the two plants studied; other factors may also interfere. The electric field has been reported to affect plants in a stressful manner by some

researchers around the world. The plants, however, did not respond in the same way. This required further studies in plant physiology and biochemistry on plants under an electric field.

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