Ecophysiological and Molecular Responses of Two *Zygophyllum* Species to Environmental Pollution

A thesis

Submitted in partial fulfillment for M.Sc. Degree
In Botany (Ecology)

By

Hend Ahmed Kamel Ali Saleh
B. Sc Botany 2005 (Fac. Of Science, Ain Shams University)

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Faculty of Science
(2011)

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الإستجابات الفسيولوجية والجزيئية لنوعين من الرطريط للتلوث البيئى

رسالة مقدمة

للحصول على درجة الماجستير فى علم النبات

(بيئة نباتية)

من

هند أحمد كامل على صالح

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كلية العلوم

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[٢٠٠٥]

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Abstract

The present investigation was conducted to study the effect of environmental pollution on the performance of two *Zygophyllum* species *(Zygophyllum album* L. f. and *Zygophyllum coccineum* L.*)* grown in desert ecosystems. Two different locations were selected in South Sinai, Egypt to achieve such goal; the first location was downwind in the vicinity of a gypsum factory (polluted location, Ras Malaab) and the other one was upwind and 25 km away from the factory (unpolluted location, Wadi Thal). The effects of gypsum dust pollution on element concentrations, leaf succulence, carbohydrate contents, chlorophyll and carotenoid contents, antioxidant enzymes (ascorbic acid oxidase, glutathione peroxidase and superoxide dismutase, catalase) and lipid peroxidation (determined as malondialdeyde) of both *Zygophyllum* species were analyzed. Furthermore, alterations in plasma membrane lipid composition and tissue polypeptide patterns of *Zygophyllum album* and *Zygophyllum coccineum* were studied in the two selected locations. Gypsum dust emitted from the factory cause an increase in the concentration of some elements (Na, Ca, Cl, Al, Zn, K and Fe) in the soil of Ras Malaab area while decreased the soil pH (from 7.28, 7.09 and 7.22 to 5.73, 5.37 and 6.24). Pollution increased the leaf

succulence and concentrations of the studied elements, more so with Ca^{+2} and Al^{+3}. The carbohydrate contents were changed, as soluble sugars increased with pollution while polysaccharides showed a remarkable decrease. Chlorophyll a and b contents decreased in plants under pollution, but the carotenoids increased in plants near the gypsum factory. The activities of ascorbic acid oxidase, glutathione peroxidase and superoxide dismutase were increased whereas that of catalase was decreased in both species under pollution conditions. Lipid peroxidation increased in both species in response to soil pollution. Different classes of plasma membrane lipids (phospholipids, glycolipids, sterols) as well as different phospholipids species were altered in *Zygophyllum album* and *Zygophyllum coccineum* as a result of soil pollution. Under soil pollution there were remarkable changes in the plasma membrane free fatty acids resulting in an increase in saturation/unsaturation ratio of both species. Qualitative differences in protein patterns were observed in both species under pollution conditions. These changes were discussed in relation to plant performance under environmental pollution.

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Introduction and literature review

Introduction

Heavy metals at low doses are essential micronutrients for plants, but in higher doses they may cause metabolic disorders and growth inhibition for most of the plants species **(Fernandes and Henriques, 1991).** Heavy metal pollution inhibits some physiological processes such as respiration, photosynthesis, cell elongation and affect plant water relationship as well as mineral nutrition **(Zornoza *et al*., 2002)**. Large areas of land are contaminated with heavy metals resulting from urban activities, agricultural practices and industry **(Khan *et al*., 2000; Ciemense, 2001)**.

Damage of the cellular membranes, especially the plasma membrane, is one of the primary events in heavy metal toxicity in plants **(Janicka *et al*., 2008)**. Disruption of membrane integrity is thought to be an effect of a complex interaction between heavy metals and functional groups of membranes. Metal ions are easily bound to both the sulphydryl groups of proteins and the hydroxyl part of phospholipids **(Devi and Prasad, 1999)**. They can also replace calcium ions at its essential sites on the membranes **(Breckle and Kahle, 1991)**. These deleterious events can result in an increase of non-specific membrane permeability and a parallel decrease of specific transporting activities, which

disrupt the ionic homeostasis and subsequently the activities of many enzymes crucial for basic cell metabolism.

Reactive oxygen species (ROS) are regarded as the main source of damage to cells under biotic and abiotic stresses **(Mittler, 2002; Candan and Tarhan, 2003; Gara *et al.,* 2003; Vaidyanathan *et al.,* 2003)**. This is because under normal conditions production and destruction of ROS is well regulated in cell metabolism **(Mittler, 2002)**. When a plant faces harsh conditions, ROS production will overcome scavenging systems and oxidative stress will burst. ROS includes superoxide (O_2), hydrogen peroxide (H_2O_2) and hydroxyl radical ($^{\cdot}OH$) **(Mittler, 2002)**. These species of oxygen are highly cytotoxic and can seriously react with vital biomolecules such as lipids, proteins, nucleic acid, causing lipid peroxidation, protein denaturation and DNA mutation **(Mittler, 2002; Quiles and López, 2004)**.

Plants have developed various protective mechanisms to eliminate or reduce ROS, which are effective at different levels of stress-induced deterioration **(Mittler, 2002; Beak and Skinner 2003)**. Antioxidant system consists of enzymatic and non enzymatic compounds. Enzymatic antioxidant includes superoxide dismutase catalase, peroxides, glutathione reductase and ascorbate reductase and non-enzymatic antioxidants are

ascorbate and glutathione **(Mittler, 2002; Candan and Tarhan, 2003)**.

The Aim of Work

The current study was, therefore, undertaken to analyze the effect of gypsum dust on the photosynthetic pigments, ash content, succulence, antioxidant enzyme activities, soluble sugars and polysaccharides, elements, proline, lipid peroxidation (MDA), plasma membrane lipids, and protein patterns of *Zygophyllum album* and *Z. coccineum* grown in desert ecosystem where heavy metal pollution dominates due to the presence of gypsum factory.

Literature review

Factory

Zahret Sinai for Gypsum is an Egyptian company established in 2000, located in the south of Sinai, occupying 100, 000 sq. M., producing 120, 000 tonnes per year of Calciend Gypsum of different types (Plaster of Paris, Anhydrite Gypsum).

Metal pollution

Environmental pollution is a threat for the survival of mankind and the most important dispute of our area **(Wang *et al.*, 2004)**. Soil contamination is one aspect of environmental pollution. Dispersal of industrial and urban wastes is a major