Journal of Medicinal Plants Studies
www.PlantsJournal.com

ISSN 2320-3862
JMPS 2017; 5(1): 130-134

Received: 19-11-2016
Accepted: 20-12-2016

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Study on allelopathic effect of *Prosopis juliflora* on mineral content of *Acacia ehrenbergiana* in Farasan Islands, KSA

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Abstract
The study indicated the allelopathy of *Prosopis juliflora* on *Acacia ehrenbergiana* through mineral analysis of both leaf extract and rhizoshere soil for both species. It was observed that all mineral content decreased in combined soil. Certain elements increased only in leaf extract of *Prosopis* as Fe^{+2} and Na^{+}. Other elements decreased in leaf extract for two species as Mg^{+2} and Mn^{+2}. This study reported that macro and microelements might be responsible for dominance of *Prosopis juliflora* and establish successfully in invaded areas.

Keywords: Allelopathy, *Prosopis*, *Acacia*

1. Introduction

Invasive plant species are responsible for disrupting ecosystems and are able to occupy large areas leading to create numerous problems for native flora and fauna (Mack *et al*. 2000 and Ehrenfeld *et al*. 2001) [25, 6]. Several mechanisms have been explained success of invasive plants. Life- history characteristics, physiological properties, rapid changes in genetics and escape from natural enemies may all contribute to introduction of invaders. (Reichard and Hamilton, 1997) [34]. More recently, allelopathy has been regarded as a potential important mechanism of plant invasion through releasing such chemicals in the introduced areas (Hierro and Callaway 2003, Inderjit *et al*. 2008) [11, 15]. The term allelopathy, derived from “allelon” the Greek word which means “each other” as well as “pathos” refers to “suffering”. This term was introduced by Hans Molisch to show beneficial and harmful effects of interactions between microorganisms and plants. However, many ecologists prefer definitions with negative effects only. For example, Lambers *et al*. (1998) [21] regarded that the growth of plant species is depressed by another because of the exudate of toxic components. Kohli *et al*. (1998) [20] and Singh *et al*. (2001) [40] have undergone several changes and defined the term ‘allelopathy’ as any direct or indirect beneficial or detrimental effects of plant species on another one by releasing chemical compounds that it diffuses into the environment. These invasion chemicals are called the “Novel Weapons”. The novel weapons hypothesis suggests that native species lack evolutionary exposure to allelochemicals which facilitate spread and regeneration of invaders through invaded areas (Callaway *et al*. 2008, Thorpe *et al*. 2009) [5, 42].
Prosopis juliflora is a leguminous species belonging to Mimosoideae. It is a well adopted shrub to harsh environment conditions of many arid zones. It has some allelopathic effects which might have been caused either by plant leachates, root exudates or fallen leaves (through decomposition of leaves) (Sazada *et al*., 2009) [38]. *Prosopis juliflora* is an invasive plant that presents as a native plant from America to Peru (GISP 2004) [8]. It was introduced and cultivated by man during the last 100-150 years for the perceived value of the trees’ products as a rich and delicious flour from pods, a major honey source in Bolivia, Jamaica and Pakistan, a good firewood with excellent charcoal, a source for fibre in the production of paper, for furniture and crafts, used for preparing various medicinal syrups, particularly for expectorants, used to arrest wind erosion in addition to stabilize sand dunes on coastal areas and for ornamentation (Hunde and Thulin, 1989) [13], (Habit and Saavedra, 1990) [9], (Poynton, 1990) [33], (Felker and Moss, 1996) [7] and (Perry, 1998) [32]. It spreads to irrigation areas, rangelands, and farmlands. It reduces the plant biodiversity by lowering the water table, preventing sunlight to reach vegetation under canopy, establishing a physical barrier on seedlings of other plant species, and releasing various chemicals that affect on the native plant

species negatively (Samuel *et al*., 2012) [37]. In the 1877, *P. juliflora* was first introduced in India as an invasive plant and spread to Pakistan, Myanmar, Sri Lanka, Thailand, Cambodia, Brunei, Vietnam, Philippines and Indonesia and reached the Arabian peninsula in the 1950s in Iran, Bahrain, United Arab Emirates, Qatar, Saudi Arabia, Kuwait, Iraq and Jordan (Burkart, 1976) [4] and (Ahmad *et al* 1996) [2].

Trees demand fourteen minerals for reproduction and normal growth. These minerals are classified as macronutrients (P, N, Ca, K, S, Mg) and micronutrients (Mn, Fe, B, Cl, Zn, Cu, Mo, Ni) according to the concentration present in normal plants. Each one is necessary for certain function in the plant. The mineral balance can affect on productivity and plant health because it plays an important role in fruit quality and disease resistance (Rietveld, 1983) [36]. All macro and micronutrients are involved in all enzymatic reactions and structural components of plant. So, mineral analysis can illustrate the growth, reproductive and physiological status of any plant (Mengel and Kirkby, 1982) [27]. The invasive plants can release secondary metabolites as inhibitory chemical compounds which are responsible for their dominance in native plant habitats. (Mooney and Cleland, 2001) [28].

The Red Sea Islands, commonly known as Farasan Islands, are located at the southern side of the Red Sea in a geographic position between 16º 20 to 17º 20 N latitude and 41º 24 to 42º 26 E longitude at an elevation of 0º to 70 m. The islands belong to Jizan district of Saudi Arabia, about 45 km off the Jizan port with an area of about 600 sq. km. The prominent Farasan Islands are: the Farasan Al-Kabir, Qummah, Sajid, Zifaf, Ad-Disan and Dumuq (Alwelaie *et al*., 1993) [3].

On the eastern side of Farasan Al-Kabir, *Acacia* vegetation occupies in areas of good soils and depressions, dominated by *Acacia ehrenbergiana* with scattered *Acacia tortilis* subsp. *tortilis*. *Acacia ehrenbergiana* presents in the silty Al-Muharraq area which are being invaded by *Prosopis juliflora* (Jacob *et al*., 2010) [16].

The present study investigated the allelopathic effect of *Prosopis juliflora* on *Acacia ehrenbergiana* through comparison of mineral analysis of leaves and rhizosphere soil for both species which are presented in Farasan Al-Kabir island combined together or separated in the field.

2. Materials and Methods

2.1 Preparation of leaf Samples

All leaf samples were washed in demineralized water, dried at about 60° until constant weight and ground in an all-steel Wiley mill to pass a 40-mesh stainless steel sieve. The dried powders of leaf samples were weighed (0.2 g) into 100-ml Kjeldahl flasks containing a glass bead. The samples were predigested with 5 ml of HNO3, cooled, digested to 5 ml of HC1 then adding 5 ml of a mixture of HNO 3 and HC1 (3 : 1). After digestion, about 40 ml of distilled demineralized water was added to each flask and the contents were brought to near boiling to ensure complete dissolution of sample. Samples were cooled, diluted to 50 ml and filtered (Heau *et al*., 1965) [10].

2.2 Preparation of soil Samples

Soil samples were collected at a depth of about one inch under the canopy. They were sieved after discarding large roots, rocks, and other extraneous materials through a quarter-inch mesh screen then dried at about 60° until constant weight.

The dried soil samples were digested as described before in preparation of leaf samples (Hillman, 1997) [12].

2.3 Preparation of Sample extract for K^+, Ca^{+2}, Mg^{+2} and Na^+ determination

Two stock solutions were prepared by dissolving and diluting with double distilled water; 300 g of glacial acetic acid and 11.112 g of ammonium fluoride each to 1 liter. 50 ml of glacial acetic acid solution was mixed with 50 ml of the ammonium fluoride solution and diluted to 1 liter to obtain the extracting solution. 2.5 ml of sample solution was transferred to 25 ml of extracting solution then shaken in an orbital shaker at 80 rpm for 2 hrs. To obtain sample extract. Extractable K^+, Ca^{+2}, Mg^{+2} and Na^+ minerals were determined with the ARL Model 34000 argon plasma spectrophotometer at spectral lines of 766.49, 317.93, 279.08, 589.59, nm respectively. The standards were prepared in the range from 0.05 to 400 mg/L (Van Lierop, 1989) [43].

2.4 Preparation of Sample extract for Fe^{+2}, Mn^{+2} and Cu^{+2} determination

149.2 g of (TEA) triethanolamine 19.67 g (DTPA) diethylenetriaminepentaacetic acid and 14.7 g CaC12.2H20 were dissolved in 200 ml of distilled water. The mixture is diluted to 9 litres. Adjust the pH to 7.30 with 6 M HCl and dilute to 10 litres. 8.5 ml of sample solution was transferred to 17 ml of extracting solution. Shake for 2 hours then shaken in an orbital shaker at 80 rpm for 2 hrs. to obtain sample extract. Extractable Fe^{+2}, Mn^{+2} and Cu^{+2} were determined with the ARL Model 34000 argon plasma spectrophotometer at spectral lines of 259.94, 257.61 and 324.75 um respectively. The standards were prepared in the range from 0.05 to 400 mg/L (Lindsay and Norvell, 1978) [24].

3. Results

The present study deals with *Prosopis juliflora,* (figure 1) and *Acacia ehrenbergiana,* (figure 2) which are presented alone in the field separated from each other as (*Prosopis* alone) and (*Acacia* alone) on the other hand, when two species are presented together in the field adhering to each other *Prosopis juliflora* and *Acacia ehrenbergiana* are called (combined *Prosopis*) and (combined *Acacia*) respectively (figure 3).

Fig 1: branch of *Acacia ehrenbergiana*

Fig 2: branch of *Prosopis juliflora*

Fig 3: *Prosopis juliflora* (at the right side) are combined with *Acacia ehrenbergiana* (at the left side)

The mineral analysis of rhizosphere soil of *Prosopis* alone, *Acacia* alone and combined one are presented in table (1), figures (4) and (5) which reveals that Fe^{+2}, Ca^{+2}, K^{+} and Mg^{+2} are presented as high content while Na^{+} Mn^{+2} and Cu^{+2} are presented as low content.

Table 1: Mineral constituents (mg/L) of rhizosphere soil of *Prosopis* alone, *Acacia* alone and combined one.

	Mg^{+2}	K^{+}	Ca^{+2}	Fe^{+2}	Na^{+}	Cu^{+2}	Mn^{+2}
Prosopis alone	97.75	92.4	26.4	345.5	2.14	0.327	5.28
Acacia alone	105	123.3	13.95	379.5	1.75	0.395	5.12
Combined soil	31.75	20.8	5.35	135.2	1.513	0.11	1.159

Ca^{+2}, Na^{+} and Mn^{+2} have the highest content in *Prosopis* alone while Mg^{+2}, K^{+}, Fe^{+2}, and Cu^{+2} have the highest content in *Acacia* alone. Moreover, all studied minerals have the lowest content in combined rhizosphere soil.

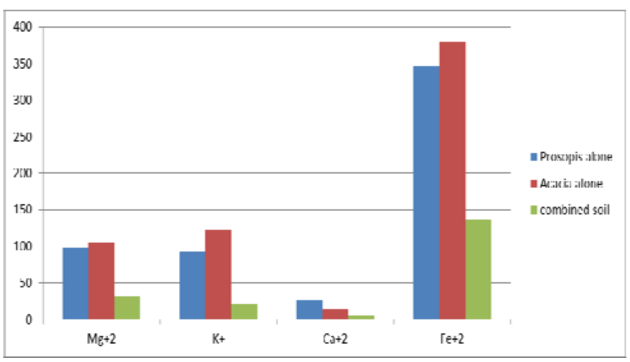

Fig 4: Comparison of rhizosphere soil among *Prosopis* alone, *Acacia* alone and combined soil in Fe^{+2}, Ca^{+2}, K^{+} and Mg^{+2} content.

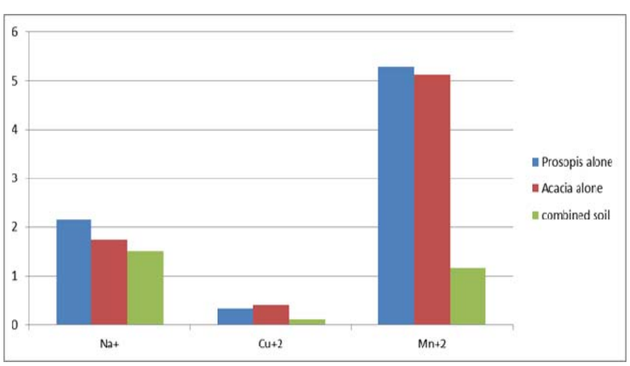

Fig 5: Comparison of rhizosphere soil among *Prosopis* alone, *Acacia* alone and combined soil in Na^{+} Mn^{+2} and Cu^{+2} content.

The mineral analysis of leaf extracts of *Prosopis* alone, *Acacia* alone, combined *Prosopis* and combined *Acacia* are presented in table (2), figures (6) and (7) which reveals that K^{+}, Ca^{+2}, Fe^{+2} and Cu^{+2} have the highest content in combined *Prosopis* while Na^{+}, Mg^{+2} and Mn^{+2} have the highest content in *Acacia* alone. On the contrary, Mg^{+2},Ca^{+2} and Na^{+} have the lowest content in combined *Acacia* while K^{+} and Cu^{+2} have the lowest content in *Acacia* alone. Moreover, Fe^{+2} and Mn^{+2} have the lowest content in *Prosopis* alone and combined *Prosopis* respectively.

Table 2: Mineral constituents (mg/L) of leaf extracts of *Prosopis* alone, *Acacia* alone, combined *Prosopis* and combined *Acacia.*

	Mg^{+2}	K^{+}	Ca^{+2}	Fe^{+2}	Na^{+}	Cu^{+2}	Mn^{+2}
Prosopis alone	22.3	80	139.3	6.585	3.76	0.093	0.398
combined *Prosopis*	17.4	98.7	144.4	83.5	11.08	0.094	0.309
Acacia alone	23.7	40	92.5	20.6	11.33	0.069	0.541
combined *Acacia*	12.2	59.3	51.2	17.5	1.71	0.087	0.347

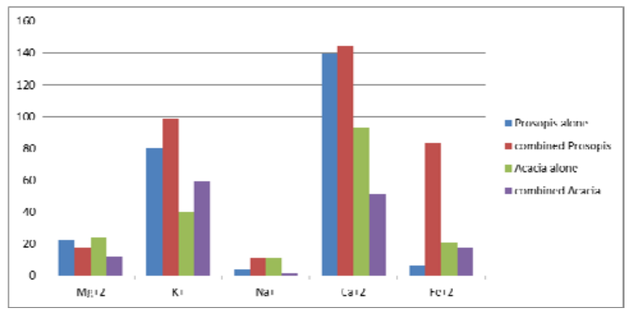

Fig 6: Comparison of leaf extracts among *Prosopis* alone, *Acacia* alone and combined *Prosopis* and combined *Acacia* in Fe^{+2}, Ca^{+2}, Na^{+}, K^{+} and Mg^{+2} content.

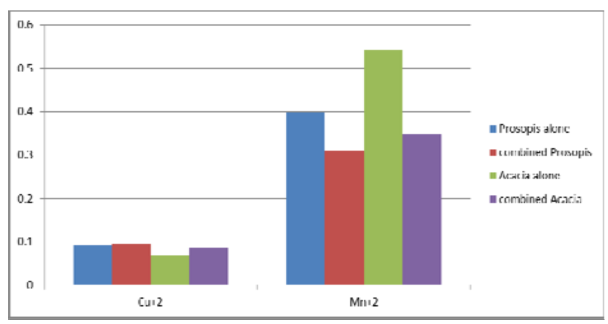

Fig 7: Comparison of leaf extracts among *Prosopis* alone, *Acacia* alone and combined *Prosopis* and combined *Acacia* in Mn^{+2} and Cu^{+2} content.

4. Discussion

All mineral content in combined soil of the present study is decreased than in separated soils. The deficiency of mineral content affects the normal metabolism of the plant. Mineral content of soils in a specific community may help to explain the nature of competition between plants for biological resources like water, nutrients, light etc. (Richardson *et al*., 2000; Sharma and Raghubanshi, 2009) [35, 39]. It has already been established that invasive plants become more dominant over native ones through release of allelochemicals causing nutrient deficiencies to the native plants as they have very high uptake of mineral nutrients compared to native plants (Klironomos, 2002 and Li *et al*., 2006) [19, 23] and compete more better because they use light and nutrients resources more efficient (Kercher and Zedler, 2004) [18]. Allelochemicals are metabolic bi-products which cause growth inhibition for neighboring plant by affecting physiological processes such as respiration, celssssl division, alteration of osmotic potential, decreasing of shoot turgor pressure (Maryam *et al*., 2013) [26] and shortage for water and ion uptake (Inderjit, 1996 and Abhilasha *et al*.,2008) [14, 1]. This shortage is obvious in this study when *Prosopis* and *Acacia* are combined, Na^{+} content is increased in combined *Prosopis* leaf extract but decreased in combined *Acacia*. More or less Ca^{+2} content is not changed in combined *Prosopis* leaf extract but it is decreased in combined *Acacia*. On the other hand, Mn^{+2} content is decreased in both combined species.

Chelation processes could affect plants by making metals more bioavailable for certain plant than the other and altering synergistic effects of metals between neighboring plants (Nikki and Scott, 2010) [30]. From this point of view, Fe^{+2} content is increased vigorously in combined *prosopis* leaf extract but it is changed little in combined *Acacia.* However, K^{+} and Cu^{+2} contents are increased in both combined species.

There are types of allelochemicals regarded as mineral cycle drivers which modify some of the most basic aspects of the physical and chemical substrates in the environment and influence on surviving and regeneration of certain plants (Kelly *et al*. 1998) [17]. There are some metals which are undergone severe competition in the soil from utilization of plants by reduction of their persistence, concentrations and biological activities through such processes as chemical transformation (Okumura *et al.,* 1999) [31] or polymerization (Mulatu *et al*., 2009) [29]. It seems that decreasing of Mg content in both species refers to the importance of magnesium to plant which regarded as a major signal for controlling plant growth. It is also the key elemental constituent of chlorophyll; the light-harvesting pigment of photosynthetic plants (Lehninger, 1970) [22].

The allelopathy of this study shows a susceptible and potential model of invasion in natural system. It tries to describe the mechanisms that drive the dramatic transformation of the ion tolerance between two species. (Hierro and Callaway, 2003) [11].

5. Conclusion and recommendation
The allelopathy plays an important role on changing mineral content of the soil. This changing influences on both macro and micro elements. The most mineral uptake presents in Ca^{+2} and Fe^{+2} for the invasive plant (*Prosopis juliflora*). Severe competition on essential elements as Mg^{+2} leads to more reduction in the soil. Other studies should be done on anion elements analysis besides, determination types of allelochemicals through phenolic compounds, alkaloids and terpenoids analysis.

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