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Plant Soil Relationships of Ten Orchard Species in Albaha, Saudi Arabia

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ABSTRACT. The plant soil relationships of ten orchard species growing in Al-Aqieq valley (1900 m. a.s.l., lat. 20° 1′, longt. 41° 38′, in Al-Baha region, Saudi Arabia) were investigated. The studied plants were: *Citrus aurantifolia, C. reticulata, C. sinesis, Prunus americana, P. armeni, P. persica; Punica granatum; Pyrus malus; Trifolium* sp. and *Vitis vinifera.* The soil was collected from three different depths (5, 15 and 30 cm). The soil is in general sandy silt, alkaline, (pH 7.7 to 7.8), the organic matter (%) was ranging between 1 to 0.75 and the E.C. from 400 to 1300 mmhos/cm and with high chlorine content at the 30 cm soil depth. The dry weight of the studied species was greatly affected by the soil salinity and chlorine content. Nutrients uptake was not efficient except for potassium which accumulated in the plants greatly over its content in the soil.

Keywords: Orchard trees, *Trifolium* sp., nutrient elements.

Introduction

The content of nutrient elements and their allocation from different types of soils was extensively studied. Deficiency of one or more elements in the soil is one of the major reasons for poor cultivation of the soils. Attempting for reclamation of such type of nutrients deficient soils depends on addition of different elements by fertilization. But excessive use of fertilizers will affect the nutrients balance in the soils which is reflected on their crops yield or even on the sustain ability of the cultivated species. However, it is well known "as an example", that increased amount of Na^+ ions in the soil antagonizes with the absorption of many ions especially K^+ ions (*e.g.* Wutcher *et al.*,[1]).

In recent years there has been increased interest in the investigation of the relationships between the nutrient status in the soil and tree species in the orchard fields (*e.g.* Smith *et al.*[2], Feller[3], Paulilo and Felippe[4]).

Tree species are characterized by the utilization of nutrient elements from different soil horizons, but this is affected mainly by the soil types and edaphic factors.

All over Saudi Arabia different tree species including fruit trees are successfully grown, however, the plant soil relationships of orchard area is the least investigated. The cultivated trees suffered from low productivity in the investigated area of study. Serious losses of fruit production and in some cases the decrease in storage quality of the fruits were considered results of nutrient elements disorder in the soil (Asher *et al.*[5]; Smith *et al.*[6] and Smith and Clark,[7]). Therefore the present work is a trial to study the relationships of dry weight, water content and some nutrient elements of ten orchard plants (*Citrus aurantifolia, C. reticulata, C. sinesis, Prunus americana, P. armeni, P. persica; Punica granatum; Pyrus malus; Trifolium* sp. and *Vitis vinifera*) with the soil characters. The present study will concentrate on the relative concentration ratios (RCR) between the contents of Ca, Mg, K, Na and Cl in leaves of these ten plants and the water soluble content of these elements in the soil.

Materials and Methods

The present work was carried out on three species of each of *Citrus* (*aurantifolia, reticulata* and *sinesis*) and *Prunus* (*americana, armeni,* and *persica*) in addition to *punica granatum, Pyrus malus* and *Vitis vinifera* and the crop under orchard trees *Trifolium* sp. which are cultivated extensively in the study area. Soil samples were collected at 5, 15 and 30cm depths approximately from points surrounding and close to the trunk of each tree. The soil samp were air dried at the room temperature (20° ± 2°C), seived from 2mm diameter and analyzed for some physical and chemical properties, according to Piper[8]. The determination of Ca, Mg, K and Na was carried out by using a flame photometer and an atomic absorption flame photometer (Shimadzu AA-670) as mentioned in Allen *et al.*[9]. For the determination of Cl, the method of Jackson and Thomas[10] was used. Fully expanded leaf samples were collected from the different sides and different heights of the tree canopy. The leaves were weighed as fresh and dry in an aerated oven at 75°C to constant weight, then from the two weights water contents were calculated. The dry leaves were ground into a fine powder and samples (0.5g) were extracted by 100ml glacial acetic acid at 80°C for three hours in order to determine the contents of Ca, Mg, K, Na and Cl according to Yeo and Flowers[11]. Another 0.5g dry samples were used for organic matter and ash determinations using loss on ignition, the dry samples were ignited in a mufful furnace at 550°C. The relative concentration ratios (RCR) of the leaves nutrient elements to those of soil were calculated for the ten studied orchard species.

Standard deviations of the recorded data and their correlation and regression equations were calculated according to Snedecor and Cochran[12].

The Study Area

The present investigation was carried out in Al-Aqieq valley, 1900 m.a.s.l., lat. 20° 18′ long. 41° 38′, at Al-Baha region in the south west of the Kingdom of Saudi Arabia. This area is characterized by 332mm annual rainfall and a mean annual temperature of

17°C with a maximum temperature of 22.6°C in June and and a minimum of 11.5°C in January (Hajar,[13]). The average relative humidity is 35.1% and average wind velocity is 7.4km/h. The humid season extends from December to May while the dry one extends from June to November.

Results

The mechanical analysis of the soil in the study area (Table 1) indicated that more than 90% of the soil particles are between 2-0.02mm diameter. Low contents of sand and fine clay particles were recorded especially at the top layer compared to the 30cm depth layer. Organic matter was low and decreased by soil depth. The organic matter at the 30cm depth was about 75% of that of the surface layer. The pH of soil water extracts was slightly alkaline and there were negligible differences between the soil depths. The electrical conductivity (EC) of the soil extracts increased by more than double from the surface layer to 30cm layer. EC records in the soil indicated that the soil is slightly saline.

TABLE 1. Soil particles (%), organic matter (%) and water content (g/g dry wt.) for the soil of the study area.

Soil depth cm	Soil particles				Organic matter %	Water content
	> 2 mm	2 – 0.2 mm	0.2 – 0.02 mm	< 0.02 mm		
1 - 5	3.4	15.1	73.6	7.9	1.0 ± 0.03	0.058 ± 0.01
5 - 10	3.1	15.1	73.6	8.2	0.99 ± 0.05	0.110 ± 0.01
10 - 30	4.5	24.1	66.0	5.4	0.75 ± 0.05	0.110 ± 0.01

The content of nutrient elements in soil (Table 2) shows high calcium and low sodium contents. The content in monovalent cations (K + Na) was only about half the content of the divalent ones (Mg + Ca). The surface layer contained less K, Na, Ca and Mg in comparison with 30cm depth. On the other hand, the content of chloride was higher at the surface layer than at the 15cm layer but it increased greatly at the 30cm layer.

TABLE 2. Nutrient elements (K, Na, Ca, Mg and Cl) contents (mmoles/g d.wt), pH and electrical conductivity (EC, mmhos/cm) in the soil of study area.

Soil depth mm	K	Na	Ca	Mg	Cl	pH	EC
1 - 5	2.64 ± 0.03	2.16 ± 0.04	5.5 ± 0.0	4.3 ± 0.2	1.6 ± 0.2	7.78	600
5 - 10	2.12 ± 0.10	3.31 ± 0.13	15.0 ± 1.9	3.8 ± 0.2	1.2 ± 0.1	7.74	400
10 - 30	3.97 ± 0.20	3.31 ± 0.10	20.2 ± 1.3	4.3 ± 0.4	8.0 ± 2.3	7.81	1300

The results of Table (3) indicate different leaf water contents for the studied species. *Trifolium* sp. leaves contained the greatest water content while those of *Citrus sinesis* contained the lowest one compared to the other species. There were notable differences in the water content of the species of the same genus especially *Citrus* species where *C. sinesis* contain nearly four times leaf water content of *C. aurantifolia.* The leaf dry weights varied also by species. The maximum dry weight was found in the leaves of *C. sinesis* and the minimum was by *Prunus americana.* The organic matter content in

leaves of the study orchard species correlated significantly (r = 0.402) with the leaf water content. The best regression equation governing the relationship between leaf water content and organic matter was linear and it was as:

$$\text{Leaf organic matter} = 43.09 + 3.75 \text{ water content.}$$

TABLE 3. Dry weight (g), water content (g/g, d.wt) and organic matter (%) for the leaves of the study plants.

Plant species	Dry weight	Water content	Organic matter
Citrus aurantifolia	0.80 ± 0.06	1.5 ± 0.02	57.6 ± 4.2
C. reticulata	0.87 ± 0.02	1.3 ± 0.05	49.6 ± 0.7
C. sinesis	2.11 ± 0.01	0.4 ± 0.01	20.7 ± 0.7
Prunus americana	0.45 ± 0.03	1.3 ± 0.10	39.4 ± 5.3
P. armeni	0.84 ± 0.05	2.0 ± 0.20	55.3 ± 4.0
P. persica	0.79 ± 0.02	1.5 ± 0.10	58.9 ± 1.6
Punica granatum	0.99 ± 0.02	1.0 ± 0.05	46.7 ± 1.4
Pyrus malus	0.73 ± 0.03	1.7 ± 0.01	64.9 ± 0.5
Vitis vinifera	0.80 ± 0.02	2.8 ± 0.10	59.6 ± 1.8
Trifolium sp.	0.97 ± 0.19	4.4 ± 1.1	48.8 ± 8.4

The maximum content of organic matter was found in the leaves of *Pyrus malus* and the minimum one was of *Citrus sinesis.*

The content of nutrient elements in the leaves of the studied species (Table 4) varied with species. The content of the divalent cations (Ca and Mg) was greater than the content of monovalent ones (K and Na) in all species except in *Trifolium* sp., *Prunus armeni* and *Pyrus malus.* The leaves of the three species contained great amounts of K. It is also notable that the leaves of *Citrus* sp., *Vitis* sp. and *Trifolium* sp. leaves contained the highest content of Ca while *Prunus* sp. contained the lowest content.

TABLE 4. Nutrient elements (K, Na, Ca, Mg and Cl) content (mmoles/g d.wt) in the leaves of study plants.

Plant species	K	Na	Ca	Mg	Cl
Citrus aurantifolia	2.48 ± 0.03	1.85 ± 0.02	2.85 ± 0.09	2.46 ± 0.20	0.54 ± 0.09
C. reticulata	2.56 ± 0.00	1.90 ± 0.01	3.55 ± 0.07	2.42 ± 0.01	0.50 ± 0.04
C. sinesis	2.53 ± 0.01	1.74 ± 0.07	5.10 ± 0.05	3.05 ± 0.09	0.16 ± 0.05
Prunus americana	3.14 ± 0.11	1.32 ± 0.01	0.02 ± 0.00	3.71 ± 0.05	0.69 ± 0.17
P. armeni	4.88 ± 0.09	1.74 ± 0.03	0.04 ± 0.00	3.20 ± 0.06	0.48 ± 0.16
P. persica	3.00 ± 0.12	1.60 ± 0.04	0.91 ± 0.06	4.50 ± 0.14	0.42 ± 0.10
Punica granatum	1.28 ± 0.00	0.46 ± 0.01	0.72 ± 0.02	3.22 ± 0.11	0.33 ± 0.04
Pyrus malus	3.33 ± 0.02	1.91 ± 0.00	2.00 ± 0.02	2.15 ± 0.05	0.56 ± 0.18
Vitis vinifera	2.56 ± 0.00	2.31 ± 0.08	3.72 ± 0.10	2.32 ± 0.05	0.56 ± 0.12
Trifolium sp.	4.64 ± 0.16	1.91 ± 0.00	4.51 ± 0.06	1.65 ± 0.14	0.34 ± 0.07

Concerning the individual elements, it is found that the highest content of each K, Na, Ca, Mg and Cl was in *Prunus armeni, Vitis vinifera, Citrus sinesis, Prunus persica* and *Prunus americana* respectively. The lowest values of K and Na were in *Punica granatum,* of Ca in *Prunus americana,* of Mg in *Trifolium* sp. and of Cl in *Citrus sinesis.*

The statistical analysis of the contents of nutrient elements in the leaves of studied orchard species (Table 5) showed that there were negative correlations between leaf dry

weight and each of water contents, organic matter, K, Mg, and Cl, but the coefficients of correlation were significant only with organic matter and chlorine content. Leaf dry weight and Ca content exhibited also a significantly positive correlation. It is also notable that in the studied plants leaves Mg content correlated negatively with the water content, organic matter, K, Na, Ca and Cl, but the coefficient of correlation was significant only with a Ca content. The equations of significant correlation that governed the variations of leaf dry weight with each of organic matter, Ca and Cl content are:

$$\text{Dry weight} = 69.9 - 21.20\ \text{O.M.}$$
$$\text{Dry weight} = -0.10 + 2.61\ \text{Ca}$$
$$\text{Dry weight} = 0.74 + 0.30\ \text{Cl}$$

Table 5. Correlation matrix of the measurements for the orchard species leaves.

Measurements	Dry weight	Water content	Organic matter	K	Na	Ca	Mg	Cl
Dry weight	0.000							
Water content	- 0.423	0.000						
Organic matter	- 0.728*	0.534	0.000					
K	- 0.178	0.582	0.187	0.000				
Na	0.012	0.493	0.283	0.448	0.000			
Ca	0.612*	0.171	- 0.331	0.063	0.551	0.000		
Mg	- 0.055	- 0.524	- 0.172	- 0.191	- 0.479	- 0.641*	0.000	
Cl	- 0.872***	0.249	0.563	- 0.477	0.213	0.477	0.003	0.000

n = 6
*Significant at $P < 0.05$
***Significant at $P < 0.001$

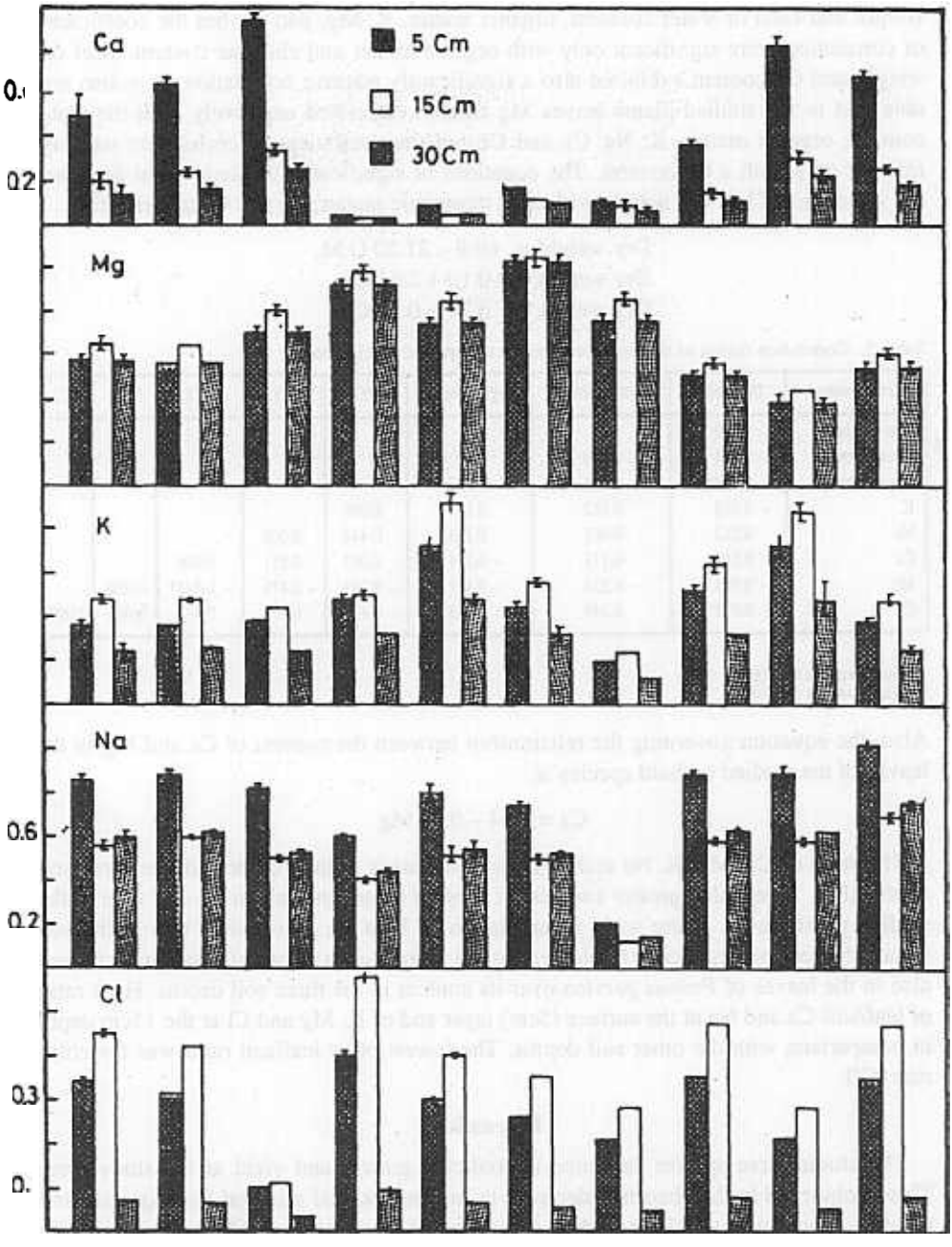
Also, the equation governing the relationship between the content of Ca and Mg in the leaves of the studied orchard species is:

$$\text{Ca} = 3.54 - 0.29\ \text{Mg}$$

The ratio of Ca, Mg, K, Na and Cl content in leaves to their content in the three soil depths (Fig. 1) revealed greater contents of most of these nutrients in the soil than in the studied plant leaves. There were accumulation of K in the leaves over that in the soil for all studied species except *Punica granatum.* Magnesium accumulation was achieved also in the leaves of *Prunus persica* over its content in the three soil depths. High ratio of leaf/soil Ca and Na at the surface (5cm) layer and of K, Mg and Cl at the 15cm depth in comparison with the other soil depths. The lowest plant leaf/soil ratio was for chlorine (Cl).

Discussion

The studied tree species exhibited unpredicted growth and yield at the study area. This is observed in the abnormal decrease in tree height, leaf size and fruits quality and quantity. The low yield of the studied species could be a result of unfavourable climatic and soil unfavourable conditions. The soil of studied area is slightly saline and alkaline in mature conditions which was early know to inhibit plant growth (*e.g.* Flowers *et al.*[14]; Greenway and Munns[15], and Elhaak and Wegmann[16]). Existing salinity level in the soil of the study area indicated that the studied orchard trees are sensitive to salinity.



Ca, Mg, and content

trus *Pyrus malus* *Trifo* *cinesis.* *inifera.*

The dry weight of leaves indicated that *Citrus aurantifolia* and *Prunus americana* were the most salinity sensitive species compared to the other *Citrus* and *Prunus* species. The soil organic matter was low which is reflected on the soil fertility and water holding capacity where the soil water content was near the soil hygroscopic moisture. The low moisture content in the soil most of the year has affected the leaves water content of the studied species. The latter correlated positively with the plant leaves organic matter content. On the other hand this low moisture content inhibited greatly the nutrient elements uptake needed for plant growth on one side and for osmoregulation on the other. The role played by accumulation of mineral elements in osmoregulation in response to salinity was found by *e.g.* Hellebust[17], Jefferies[18] and Migahid and Elhaak[19]. It is also notable that the orchard species leaf dry weights correlated negatively with chlorine and positively with Ca contents. Leaf Ca and Mg contents correlated negatively with a significant linear relationship which indicated an antagonistic effect between both elements in the study species.

The ratio of leaf/root content of K, Na, Ca, Mg and Cl indicated low uptake and accumulation of these elements in the studied species leaves except for K which accumulated up to its content in the soil. The high content of K in the leaves of the studied species is an adaptive response in order to decrease stomatal water loss in such dry area. The role of K in stomatal control for water loss was reviewed by Greenway and Munns[15]. The ratio of Na and Cl indicated unequivalent uptake of the two elements by the study orchard species, a result which was also found by Hellebust[17]. Na was found to be more absorbed than chlorine which increased in the soil. However, the low yield of studied orchard species could be a result of the slight soil salinity in addition to the low nutrients uptake and high chloride content of the soil (Rogers and West[20]).

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علاقة النبات بالتربة لعشرة من النباتات المثمرة بمنطقة الباحة بالمملكة العربية السعودية

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المستخلص . تم في هذا البحث دراسة علاقة النبات بالتربة لعشرة أنواع من النباتات المثمرة التي تنمو في وادي العقيق (حيث توجد منطقة الدراسة على ارتفاع ١٩٠٠م فوق سطح البحر وتقع على خط عرض ١- ٢٠ْ وخط طول ٣٨- ٤١ْ في منطقة الباحة بالمملكة العربية السعودية .

هذا وقد درست النباتات التالية : الليمون ، اليوسفي ، البرتقال ، البرقوق ، المشمش ، الخوخ ، الرمان ، التفاح ، البرسيم والعنب .

(*Citrus aurantifolia; C. reticulata; C. sinesis; Prunus americana; P. armeni; Punica granatum; Pyrus malus; Trifolium* sp. and *Vitis vinifera*).

وقد جمعت التربة من ثلاث أعماق مختلفة (٥ ، ١٥ و ٣٠ سنتيمتر) . هذا وتشير النتائج إلى أن التربة بشكل عام طميية رملية وقلوية (الرقم الهيدروجيني ٧,٧-٨,٧) والكربون العضوي يتراوح بين ١-٧٥,٠٪ . والتوصيل الكهربائي بين ٤٠٠ و١٣٠٠ ملي مولز/ سم ، مع ارتفاع في كمية الكلورين على عمق ٣٠ سم .

وتشير النتائج إلى أن الوزن الجاف للأنواع النباتية قيد الدراسة تأثر تأثرًا واضحًا بملوحة التربة ومحتواها من الكلورين . كما إن امتصاص النباتات المدروسة للمغذيات لم يكن فعالاً ، ماعدا في حالة البوتاسيوم ، والذي فاق في تراكمه في النبات محتواه في التربة .