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Original Research

Impact of dry climate on the distribution of mineral elements in soil layers and its relationship with plant development

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ABSTRACT

Aim: This study evaluates the effect of dry climate on mineral distribution in soil and its correlation with their plant growth. **Methods:** Soil samples from different depths (0.0-100 cm) and ten developing plants above them were collected for one year from three districts (Old-Dir'iyah, Jenadriah and Muzahimiyah) in Riyadh, KSA. **Results:** The results revealed that all soil samples had alkaline pH and contain high total carbonates concentrations. Total dissolved salts recorded the highest content in Muzahimiyah area under *Zygophyllum migahidii*, *Moricandia sinaica* and *Heliotropium bacciferum* plants which indicates their high-salinity tolerance. Chemical analysis of soil samples showed great variation in the anions and cations content. Among the studied anions in soil samples, sulphate had the highest record while phosphorus was the lowest. Calcium and iron were the highest and the lowest cations found in soil content respectively. Sodium, potassium and magnesium were varied in different regions among different soil depths under the plants. Accumulation of sodium, magnesium, potassium, phosphorus and total carbonates were recorded in the studied plants which assist them to confront drought in both the summer and winter. Results showed that there is variation in ash content among different plants. **Conclusion:** Mineral persistence inside plants revealed their defiance to drought.

KEY WORDS: Minerals, nutrients, soil, plants, drought, climate

INTRODUCTION

Soil properties play an important role in the distribution of plants in terms of pH, salts, minerals content and soil texture which effect on its field capacity. Natural vegetation is closely related to the soil quality and topography.

Plants survive under drought suffered from lack of water resources and increase of evaporation intensity, so they have morphological, physiological and anatomical structure to face lack of affordable water in the soil and climate warming. Drought can affect mineral elements uptake and impair translocation of some nutrients. Drought reduces both nutrient uptake by the roots and transport from the roots to the shoots, because of restricted transpiration rates and impaired active transport and membrane permeability [1].

The role of plant cycling on the distribution of nutrients (N, P and K) comes from studies on horizontal nutrient patterns, usually associated with 'islands of fertility' in desert ecosystems. Such plants as shrubs in deserts or trees in savannas often accumulate organic matter beneath their canopies, enriching soil nutrient pools as a result of uptake by lateral roots beyond the canopy and subsequent cycling under it [2].

A better understanding of the role of mineral nutrients in plant resistance to drought will contribute to an improved fertilizer management in arid and semi-arid areas and in regions suffering from temporary drought [1]. Therefore, this study was carried out to determine the effect of climate on mineral availability, uptake, transport and accumulation in soil and plants.

BACKGROUND INFORMATION

The meteorological data for a ten years period (1993-2003) were obtained from Presidency of Meteorology and Environmental Protection. These are presented in the climatic diagram (Figure 1). These data indicate that the climate is hot with temperature extremes and is decidedly arid with a low and high erratic rainfall, and a high evaporation potential [3]. The mean temperature in the summer period, reach 36°C. While the annual monthly mean of the rainfall during the winter period, around 10.8 mm. This arid climate greatly affected the vegetation in the studied area.

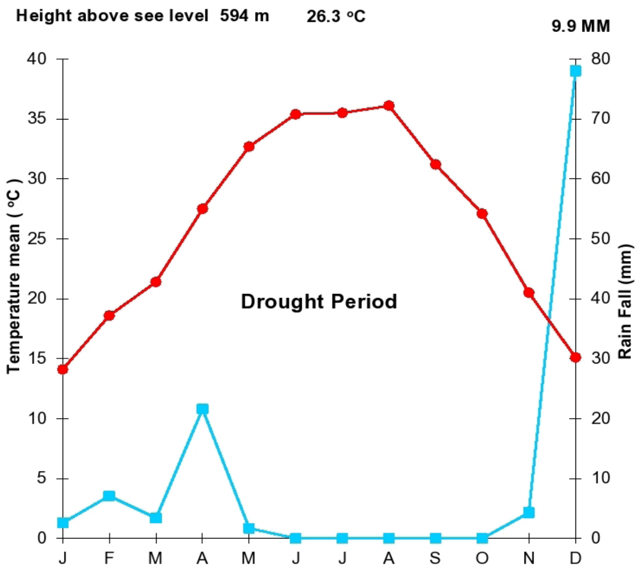

Figure 1. Climate chart for Riyadh region in Saudi Arabia for a period of ten years (1993-2003)

Geologically, Riyadh region consists of two main sections: Arabian Shield in the west of the region and Arabian Shelf in the east of the Najd Plateau which consists of a variety of geological formations increases in their thickness during direction to the east of Riyadh region around the Arabian Gulf minerals content [4].

In Saudi Arabia, soil originating from several geological sources. In Arabian Shield, it consisted from degradation of igneous and metamorphic rocks while in Arabian Shelf most soils consisted of sandy, clay and limestone rocks. According to soil content from limestone configurations, it divided into major groups. Calcareous soils (Pedocals) which are the most important soils in arid and semi-arid areas. Sierozem soils that prevail most desert areas and is characterized by a lack of organic material and the accumulation of salts on its surface. Physical and chemical properties of the soil are influenced mainly by climate change and vegetation developing on it [5].

MATERIAL AND METHODS

Sampling and analysis

Soil samples were collected from three selected areas (Old-Dir'iyah, Jenadriah and Muzahimiyah) located in Riyadh region at various depths under the studied plants starting from the soil surface to the root zone (zero -100 cm) during winter and summer of the year 2014. Soil samples were air-dried crushed and passed through 2 mm mesh sieve and stored at ambient temperature prior to analysis. Chemical properties of the soil was measured in terms of pH, organic carbon (OC), total carbonates, carbonates (CO_3^{2-}), bicarbonates (HCO_3^{-}), total dissolved solids (TDS), chlorides ($C1^{1-}$), sulphates (SO_4^{2-}) and phosphates (PO_4^{3-}). Collection, preparation and chemical analyses of soil samples were performed according to Berg and Gardner and USDA [6, 7].

Ten plants were collected from the selected areas as the following: in Old-Dir'iyah: *Datura innoxia* Mill and *Capparis spinosa* L.; in Jenadriah: *Rhazya stricta* Decne, *Cassia italica* Mill. (sprengl) and *Calotropis procera* (Ait.) Ait.F.; in Muzahimiyah: *Moricandia sinaica* (Boiss.) Boissa., *Zygophyllum migahidii* Hadidi., *Zilla spinosa* (Turr.) Prantl., *Heliotropium bacciferum* Forssk. and *Rhanterium epapposum* Oliv. Leaves part of plant samples were oven dried at 65°C to a constant weight, ground in a Coffee grinder to powdery form and then stored for analysis.

The dried soil and plants samples were digested then the levels of Na^+, K^+, Ca^{2+}, Mg^{2+} and Fe^{3+} were determined by Atomic Absorption Spectrophotometer Schimadzu model AA-675 Series.

Statistical analysis

Data were tabulated and analyzed using Statistical Package for Social Sciences (SPSS) version 11.0 computer software package [8].

Pearson's correlation coefficient was preformed at a confidence limit 95% to examine the association of mineral elements distribution at different soil depths with plant growth.

RESULTS

Chemical characteristics of soil

Tables 1 and 2 show chemical characteristics of soil samples at different depths under the studied plants collected from the selected three areas in Riyadh region, Saudi Arabia during summer and winter of the year 2014.

It is clear from these tables that the mean value of pH in soil samples was alkaline and it ranged from 6.3 to 8.3. In the present study, it was found that alkaline pH of soil was more increase in summer than in winter through all soil layers. Also, in winter, the highest pH (7.38 -8.29) values recorded in the deep soil layer (50-100 cm) under some plants such as *Moricandia sinaica*, *Calotropis procera*, *Rhanterium epapposum*, *Heliotropium bacciferum* and vice versa in summer where the pH increase in the surface layer.

Table 1. Chemical characteristics of soil samples at different depths under the studied plants collected from the selected three areas in Riyadh region, Saudi Arabia during summer of the year 2014

Area	Plant species	Depth (cm)	pH	Organic carbon (mg/100g)	Total CO_3 (%)	Total soluble salt (mg/100g)	Anions (mg/100g)					Cations (mg/100g)				
							$C1^{-}$	SO_4^{2-}	HCO_3^{-}	CO_3^{2-}	PO_4^{3-}	Na^+	K^+	Ca^{2+}	Mg^{2+}	Fe^{3+}
Old-Dir'iyah	*Datura innoxia*	0-5	7.60	174.15	38.46	1021	90	510	20	Nil	2.85	39.37	32.20	46.53	24.18	0.37
		5-20	8.14	348.33	39.24	611	40	290	10	Nil	7.60	33.33	19.95	33.58	20.52	0.08
		20-50	8.16	176.18	39.36	196	10	110	10	Nil	2.85	20.86	8.26	16.12	9.21	0.01
		50-100	8.18	107.33	33.58	174	9	100	20	Nil	3.8	19.13	8.03	14.76	7.35	0.49
	Capparis spinosa	0-5	8.19	166.05	37.26	166	5	130	20	Nil	4.75	2.81	10.48	11.27	6.27	0.69
		5-20	8.27	105.30	40.30	160	6	130	10	Nil	3.80	4.99	4.82	6.87	3.39	0.08
		20-50	8.18	52.65	42.42	81	4	110	10	Nil	7.60	1.16	4.18	6.83	2.55	0.11
		50-100	8.29	56.70	42.94	102	4	110	20	Nil	2.85	1.06	4.10	10.28	3.01	0.06
Jenadriah	*Rhazya stricta*	0-5	7.94	133.65	38.26	250	30	120	30	Nil	2.85	12.95	16.88	24.59	15.88	0.13
		5-20	7.83	212.63	37.36	212	20	100	10	Nil	3.80	7.59	9.45	17.04	9.83	0.33
		20-50	8.16	85.05	37.30	114	8	140	9	Nil	2.85	0.23	9.59	12.19	2.20	0.37
		50-100	8.19	54.68	35.34	92	9	90	9	Nil	3.80	0.74	8.78	13.17	1.60	0.26
	Cassia italica	0-5	7.84	10.13	35.86	173	7	380	10	Nil	3.80	0.99	15.35	11.49	6.85	0.03
		5-20	8.15	113.40	35.92	95	3	60	10	Nil	6.65	1.23	12.97	10.08	1.19	0.10
		20-50	7.93	107.33	36.46	165	10	30	10	Nil	2.85	3.47	32.07	11.51	4.08	0.18
		50-100	7.97	85.08	34.66	178	9	130	10	Nil	3.80	2.95	15.39	12.54	2.51	0.09
	Calotropis procera	0-5	7.97	338.18	35.48	238	20	50	10	Nil	3.80	8.05	17.07	20.03	13.61	0.25
		5-20	7.51	247.05	35.92	244	20	50	8	Nil	1.90	9.72	15.03	20.85	10.09	0.22
		20-50	7.66	131.63	35.36	223	20	20	6	Nil	3.80	7.89	9.82	28.04	7.94	0.23
		50-100	7.85	93.15	30.12	177	20	110	7	Nil	2.85	2.89	6.97	29.93	5.24	0.20
Muzahimiyah	*Moricandia sinaica*	0-5	7.81	10.13	38.66	662	10	190	8	Nil	2.85	14.95	2.55	40.86	2.26	0.34
		5-20	7.73	46.58	41.64	555	20	110	9	Nil	2.85	17.19	2.42	37.24	2.23	0.35
		20-50	7.35	54.68	43.66	729	20	250	7	Nil	2.85	25.04	1.70	44.66	0.71	0.35
		50-100	7.38	50.63	43.94	724	10	500	6	Nil	2.85	22.15	1.30	43.29	0.92	0.24
	Zygophyllum migahidii	0-5	7.37	26.34	39.70	675	20	320	6	Nil	2.85	17.90	2.08	41.36	7.45	0.60
		5-20	7.48	36.45	44.16	633	20	350	4	Nil	2.85	19.37	1.12	36.45	1.19	0.49
		20-50	7.60	38.48	44.04	677	30	290	7	Nil	2.85	19.54	1.27	34.27	2.04	0.39
		50-100	7.63	12.15	44.60	615	20	310	5	Nil	3.80	22.76	1.45	41.46	2.45	0.36
	Zilla spinosa	0-5	7.68	87.08	41.16	141	20	440	6	Nil	2.85	16.00	1.76	15.20	1.41	0.42
		5-20	7.71	48.60	42.28	297	10	20	8	Nil	2.85	18.23	1.69	20.16	2.84	0.63
		20-50	7.64	56.70	42.72	169	10	30	7	Nil	2.85	20.24	0.85	20.32	3.69	0.41
		50-100	7.82	28.35	44.20	167	10	100	8	Nil	2.85	15.24	0.01	17.00	4.02	0.36
	Heliotropium bacciferum	0-5	7.95	107.33	38.08	357	40	90	6	Nil	1.90	31.76	2.66	24.50	4.55	0.63
		5-20	7.15	48.60	40.96	825	20	440	5	Nil	1.90	17.20	1.29	56.57	0.80	0.46
		20-50	7.06	48.60	38.64	940	6	540	6	Nil	2.85	3.83	0.89	59.74	0.80	0.82
		50-100	7.45	58.72	37.86	279	6	250	4	Nil	2.85	7.98	0.75	57.53	1.03	0.71
	Rhanterium epapposum	0-5	7.85	95.18	43.14	223	30	40	8	Nil	3.80	30.26	2.53	20.39	3.31	0.67
		5-20	7.65	40.50	44.94	161	20	100	8	Nil	2.85	20.41	0.06	17.10	1.89	0.67
		20-50	7.88	14.18	44.42	455	20	70	8	Nil	2.85	23.11	0.32	18.45	0.38	0.68
		50-100	8.08	32.40	45.72	180	20	100	6	Nil	2.85	20.06	0.05	19.47	3.15	0.68

Table 2. Chemical characteristics of soil samples at different depths under the studied plants collected from the selected three areas in Riyadh region, Saudi Arabia during winter of the year 2014

Area	Plant species	Depth (cm)	pH	Organic carbon (mg/100g)	Total CO_3 (%)	Total soluble salt (mg/100g)	Anions (mg/100g)					Cations (mg/100g)				
							$C1^{-}$	SO_4^{2-}	HCO_3^{-}	CO_3^{2-}	PO_4^{3-}	Na^{+}	K^{+}	Ca^{2+}	Mg^{2+}	Fe^{3+}
Old-Dir'iyah	*Datura innoxia*	0-5	6.95	155.90	48.30	370	9	410	20	Nil	4.75	0.65	0.53	2.48	4.30	0.16
		5-20	6.94	162	45.24	229	8	70	10	Nil	4.75	0.98	0.69	3.24	5.18	0.28
		20-50	6.90	164	47.44	201	8	60	10	Nil	4.75	0.57	0.57	2.79	4.69	0.21
		50-100	6.94	105.30	44.16	195	8	70	10	Nil	3.80	0.35	0.50	2.12	2.39	0.38
	Capparis spinosa	0-5	6.90	127.58	44.40	197	9	750	9	Nil	2.85	1.04	2.64	69.92	2.34	0.16
		5-20	6.99	137.70	45.88	171	6	670	10	Nil	2.85	0.49	1.97	51.96	3.05	0.36
		20-50	7.01	115.43	46.12	86	5	740	10	Nil	3.80	0.42	1.11	43.89	2.43	0.09
		50-100	6.92	62.78	46.26	72	6	730	9	Nil	2.85	0.42	0.93	28.29	3.38	0.03
Jenadriah	*Rhazya stricta*	0-5	7.77	155.90	41.26	61	6	110	10	Nil	2.85	0.48	18.39	3.59	2.04	0.13
		5-20	7.44	30.38	39.76	76	2	90	100	Nil	1.90	0.54	13.19	4.89	2.12	0.14
		20-50	7.33	14.18	39.14	75	3	140	10	Nil	1.90	0.50	9.48	7.05	1.92	0.15
		50-100	7.43	18.23	36.62	87	6	100	9	Nil	1.90	1.04	7.59	25.03	1.68	0.17
	Cassia italica	0-5	7.80	32.40	42.38	79	3	90	5	Nil	3.80	3.18	9.32	4.89	6.89	0.19
		5-20	7.92	30.38	41.82	89	6	160	4	Nil	2.85	2.81	8.32	7.29	2.33	0.19
		20-50	7.74	44.55	41.46	119	8	90	6	Nil	0.95	2.79	7.75	20.23	2.31	0.12
		50-100	7.68	66.33	40.40	151	8	180	7	Nil	1.90	2.86	6.73	26.33	2.89	0.14
	Calotropis procera	0-5	7.71	76.95	40.12	92	3	60	10	Nil	5.70	2.05	8.69	6.86	2.95	0.19
		5-20	7.82	66.83	33.38	99	4	80	10	Nil	2.85	1.79	4.99	22.87	1.55	0.15
		20-50	7.98	74.93	32.96	108	5	30	10	Nil	3.80	2.91	3.43	29.17	2.68	0.06
		50-100	7.99	48.60	32.36	81	3	70	10	Nil	2.85	2.85	2.72	23.33	2.96	0.03
Muzahimiyah	*Moricandia sinaica*	0-5	7.52	64.80	45.42	649	50	70	5	Nil	3.80	16.59	5.97	69.50	4.60	0.20
		5-20	7.50	56.70	45.08	780	20	390	7	Nil	2.85	5.90	4.13	88.50	2.07	0.19
		20-50	7.42	50.63	40.34	983	9	430	4	Nil	2.85	3.32	2.88	172.33	1.99	0.06
		50-100	7.44	52.65	47.46	1023	10	330	3	Nil	4.75	4.48	2.85	169.33	2.12	0.08
	Zygophyllum migahidii	0-5	7.85	83.25	43.36	432	40	120	8	Nil	2.85	9.88	4.04	40.70	13.01	0.57
		5-20	7.62	72.90	42.94	235	30	160	7	Nil	1.90	6.03	2.34	30.50	3.32	0.28
		20-50	7.53	74.93	45.52	260	30	120	10	Nil	0.95	10.06	1.26	38.10	5.11	0.44
		50-100	7.52	74.93	45.76	190	10	110	8	Nil	0.95	4.61	0.99	36.90	5.10	0.38
	Zilla spinosa	0-5	6.86	125.55	41.82	990	40	160	10	Nil	3.80	18.60	2.39	21.40	5.05	0.49
		5-20	6.67	93.15	45.16	563	40	50	10	Nil	2.85	0.78	0.51	1.94	3.24	0.14
		20-50	6.33	64.80	42.32	374	20	60	10	Nil	2.85	7.96	0.81	3.65	2.79	0.59
		50-100	6.53	74.93	43.32	335	10	80	10	Nil	2.85	0.44	0.43	1.76	3.48	0.13
	Heliotropium bacciferum	0-5	7.54	147.83	44.30	441	40	260	10	Nil	0.95	42.80	6.35	71.73	5.54	0.59
		5-20	7.54	131.63	46.16	316	30	430	4	Nil	1.90	4.61	3.72	93.43	2.59	0.39
		20-50	7.42	129.60	41.68	276	30	650	9	Nil	2.85	3.69	2.77	262	1.25	0.35
		50-100	7.36	125.56	42.92	185	10	670	10	Nil	3.80	4.74	2.72	255	2.52	0.37
	Rhanterium epapposum	0-5	6.75	133.65	45.00	37	50	110	100	Nil	4.75	0.34	0.53	1.42	3.07	0.12
		5-20	6.63	111.38	44.28	128	30	90	10	Nil	2.85	2.98	5.59	5.19	4.30	0.39
		20-50	6.42	95.18	45.80	109	20	80	10	Nil	2.85	1.12	0.92	2.08	3.04	0.57
		50-100	6.47	85.50	47.30	91	10	50	9	Nil	2.85	2.43	1.70	5.49	3.96	0.45

The recorded mean TDS values of soil samples in winter were ranged from 61 to 1023 mg/100g. The highest TDS were recorded in Muzahimiyah area under *Moricandia sinaica* plant where the salinity at various depths ranging from 649 to 1023 mg/100g. The lowest TDS were recorded in Jenadriah area under *Rhazya stricta* plant where it ranged from 61 to 87 mg/100g. In summer, it is observed that TDS were higher in the surface soil layer than the rest of layers. However, the minimum and maximum of TDS (81-1021mg/100g) in summer were close to found in winter in all soils depths under study.

Low mean OC values of soil samples were observed in both summer and winter seasons. In winter, the highest value of OC was 155.90 mg/100g while the lowest was 14.18 mg/100g. In summer, OC was ranged from 10.13 mg/100g to 348.33 mg/100g. The highest means values of OC were recorded in summer in Old-Dir'iyah area under *Datura innoxia* plant and in Jenadriah area under *Calotropis procera* plant. In winter, the highest means values of OC were observed in implanted soil with *Datura innoxia* and *Capparis spinosa* in Old-Dir'iyah region while under *Heliotropium bacciferum* in Muzahimiyah region. It is noticed that OC was higher in the surface soil layers than deep ones.

It is observed a significant increase in the percentage of total carbonates in different soil layers ranging from 32.36 to 48.30% in the winter. The lowest percentages of total carbonates recorded in different soil depths were in Jenadriah area under *Calotropis procera* (32.36 – 40.12%) and *Rhazya stricta* (36.62 – 41.26%) plants. It is found that the highest percentages of total carbonates recorded in the surface layer (0.0 – 5.0 cm) were under *Datura innoxia*, *Rhazya stricta*, *Calotropis procera* and *Cassia italica* plants while under the rest of the plants recorded in the deep layer of the soil. In summer, percentages of total carbonates (30.12 – 45.72%) were close to observed in winter. It is noticed that there are variation in the accumulation of carbonate at different soil depths. The highest total carbonates percentages were under *Rhanterium epapposum* plant while the lowest under *Calotropis procera* plant in the deeper layers of the soil (50 – 100 cm).

In the present study, dissolved CO_3^{2-} was not detected in all soil samples. However, dissolved HCO^{3-} recorded with very low values in all soils areas under study.

Observed $C1^{1-}$ in soil samples was with low values in winter. The highest $C1^{1-}$ values were in the surface layers of soils in all regions. In Muzahimiyah area, the maximum value of $C1^{1-}$ (50 mg/100g) was under *Moricandia sinaica* and *Rhanterium epapposum* plants. Also, it is noticed that the $C1^{1-}$ values decreased with increasing in soil depths reaching the lowest value of 10 mg/100g in depth of 50-100cm. In Jenadriah area, the lowest $C1^{1-}$ values were ranged from 2 to 8 mg/100g. In Old-Dir'iyah region, similar $C1^{1-}$values were in soil depths (5-100cm) under *Datura innoxia* plant while the highest value of $C1^{1-}$ was in the surface layer. In summer, in Old-Dir'iyah area, the highest value of $C1^{1-}$ (90 mg/100g) was under *Datura innoxia* plant in the surface layer while the lowest value of $C1^{1-}$ (9 mg/100g) was in the deep layer (50-100cm). Also, the lowest values of $C1^{1-}$ were under *Capparis spinosa* plant and ranging from 4 to 6 mg/100g. In Jenadriah area, under *Calotropis procera* plant, similar $C1^{1-}$ values (20 mg/100g) at different depths were recorded. In Muzahimiyah area, the highest value of $C1^{1-}$ (40 mg/100g) was in the surface layer under *Heliotropium bacciferum* plant and the lowest value of $C1^{1-}$ (6 mg/100g) was in the depth (50-100cm) under the same plant.

SO_4^{2-} content found to be high in winter reaching the maximum value of 750 mg/100g in the surface layer under *Capparis spinosa* plant in Old-Dir'iyah area. Also, it is observed that SO_4^{2-}values (670-750 mg/100g) were higher in all soil layers under this plant than the rest of plants at different soil depths. In Jenadriah area, the lowest SO_4^{2-} content (30 mg/100g) was in depth (20-50cm) under *Calotropis procera* plant. In addition, low SO_4^{2-} values were recorded at different soil depths under this plant. Accumulation of SO_4^{2-} in the middle soil layers that are the root growth area was observed. In summer, it was observed that some high values of SO_4^{2-}recorded in the surface layer and others recorded in different depths of soil. Our results revealed that $C1^{1-}$ values were higher than chlorides at different soil depths in both summer and winter.

Among the studied anions in soil, PO_4^{3-} scored lower values in all depths. In winter, the maximum recorded PO_4^{3-} (5.70 mg/100g) value was in the surface layer under *Calotropis procera* plant in Jenadriah area while the minimum PO_4^{3-} (0.95 mg/100g) value was under *Heliotropium bacciferum* plant in Muzahimiyah area. In deep soil layers, the maximum PO_4^{3-} (4.75 mg/100g) value recorded under *Moricandia sinaica* plant in Muzahimiyah area. In summer, the maximum PO_4^{3-} (4.75 mg/100g) value recorded in the surface layer under *Capparis spinosa* in Old-Dir'iyah area. In Jenadriah area, equal value of PO_4^{3-} (3.80 mg/100g) recorded under each of *Cassia italica*, *Calotropis procera* plants.

It is found that Ca^{2+} recorded the highest cations in soil in all areas under study. In winter, in Muzahimiyah area, high values of Ca^{2+} (71.73 – 262 mg/100g) recorded in all soil layers under *Heliotropium bacciferum* plant. In summer, the highest value of Ca^{2+} (46.53 mg/100g) was in the surface layer in Old-Dir'iyah area under *Datura innoxia* plant. In Muzahimiyah area, low values of Ca^{2+} (24.50-59.74 mg/100g) under *Heliotropium bacciferum* plant were found when compared with winter.

Approximate Mg^{2+} values in soils of different regions were recorded in both winter and summer. In Old-Dir'iyah area, the maximum value of Mg^{2+} in soil was found under *Datura innoxia* plant in depth (5-20 cm) and *Capparis spinosa* plant in depth (50-100 cm) in winter. However, in summer, the maximum value of Mg^{2+} in soil was under these plants in the surface layer (0-5 cm). In Jenadriah area, the surface layer under *Rhazya stricta* plant had more Mg^{2+} content in summer than in winter. In Muzahimiyah area, Mg^{2+} content in soils more increase in winter than in summer. The highest mean value of Mg^{2+} (13.01 mg/100g) was under *Zygophyllum migahidii* plant in the surface layer which is twice its value (7.45 mg/100g) under the same plant and depth in summer.

In the present study, K^+ had the highest value in Jenadriah area under *Rhazya stricta* plant (18.39 mg/100g) in the surface layer followed by *Cassia italica* plant (9.32 mg/100g) in winter. The lowest K^+ value recorded in the surface layer under *Datura innoxia* and *Rhanterium epapposum* plants (0.53 mg/100g). It is observed that the highest K^+ values recorded in the surface layer of the soil (0-5 cm) except under *Datura innoxia* and *Rhanterium epapposum* plants were at depth of 5-20 cm. in Muzahimiyah area, the lowest K^+ value (0.43 mg/100g) was recorded under *Zilla spinosa* in deep soil layer (50-100 cm). in summer, it was observed increase K^+ in all soil depths. The highest K^+ value (32.20 mg/100g) was under *Datura innoxia* plant (0-5 cm) in Old-Dir'iyah area and the lowest K^+ value (0.01 mg/100g) was under *Zilla spinosa* plant (50-100 cm) in Muzahimiyah area. Also, all high K^+ values recorded in the surface layer of the soil under all plants except *Cassia italica* plant.

Comparing Na^+ levels in winter and summer in different regions, it was observed that high Na^+ values recorded in most of the depths except under *Cassia italica* plant in summer. The highest Na^+ values were recorded under developing plants in Muzahimiyah area.

Among all studied minerals in soil, Fe^{3+} is the least abundant element, which recorded highest concentration of 0.82 mg/100g under *Heliotropium bacciferum* plant in summer. The lowest concentration of Fe^{3+} (0.01 mg/100g) was recorded under *Datura innoxia* plant. The highest Fe^{3+} levels recorded at all different soil depths under all plants developing in Muzahimiyah area. In winter, the lowest Fe^{3+} (0.03 mg/100g) values were found to be in the deeper layers under *Capparis spinosa* and *Calotropis procera* plants and the highest Fe^{3+} (0.59 mg/100g) value was under *Zilla spinosa* plant in soil depth of 20-50 cm. It is noticeable that high Fe^{3+} concentrations recorded in areas with high Na^+ content.

Chemical characteristics of plants

Chemical analysis of the selected plants species leaves within the three selected habitats located in Riyadh, Saudi Arabia during summer and winter seasons is presented in Table 3.

It is clear from Table 3 that higher mean values of total carbonate content were recorded in all plant species in winter than in summer. The highest mean value of total carbonate (36.38 g%) in winter was in *Heliotropium bacciferum* plant in Muzahimiyah area while the lowest record (30.28 g%) was in *Cassia italica* plant in Jenadriah area. In summer, *Zilla spinosa* plant had the highest value of total carbonate (19.24 g%) and *Zygophyllum migahidii* plant had the lowest mean value (16.11 g%). It is observed that high total carbonate values recorded in plants species developed in Muzahimiyah area for both summer and winter followed by growing plants in Jenadriah area then Old-Dir'iyah.

Higher ash content recorded in the majority of plant species in summer than in winter except in *Moricandia sinaica* and *Zilla spinosa* plants. In summer, the highest ash content

Table 3. Chemical analysis of different plants leaves samples collected from the selected three areas in Riyadh region, Saudi Arabia during summer and winter of the year 2014

Area	Species	Season	Total CO_3 (g%)	Ash content (g%) Dry wt.	Anions			Cations (mg/100g)				
					Cl^- (g%)	SO_4^{2-} (g%)	PO_4^{3-} (mg/100g)	Na^+	K^+	Ca^{2+}	Mg^{2+}	Fe^{3+}
Old-Dir'yah	*Datura innoxia*	Summer	17.08	29.30	8.51	2.26	41.80	0.35	24.41	5.58	24.40	1.79
		Winter	30.76	15.47	9.46	4.18	63.65	13.91	23.11	6.20	24.91	0.69
	Capparis spinosa	Summer	16.94	30.67	8.89	10.43	65.55	0.46	24.27	1.60	24.27	2.89
		Winter	32.84	21.13	12.29	5.35	32.30	5.22	18.28	6.10	25.34	2.62
Jenadriah	*Rhazya stricta*	Summer	18.76	11.87	6.81	4.12	25.65	0.26	23.73	2.63	20.55	2.03
		Winter	33.06	10.41	5.12	4.01	38.00	4.49	12.43	4.53	17.37	0.79
	Cassia italica	Summer	17.14	14.50	7.94	4.87	30.40	0.15	20.50	3.99	21.53	3.26
		Winter	30.28	10.30	6.81	3.12	32.30	4.49	11.08	5.62	18.54	1.48
	Calotropis procera	Summer	17.25	15.86	6.81	7.62	23.75	6.49	21.68	3.19	25.01	0.74
		Winter	34.56	14.40	7.81	5.72	52.25	15.85	17.72	6.09	26.03	0.89
Muzahimiyah	*Moricandia sinaica*	Summer	16.37	25.30	12.77	8.02	18.05	6.74	15.43	1.59	26.20	1.33
		Winter	33.74	31.00	10.03	13.79	17.10	28.19	17.52	4.62	26.17	7.49
	Zygophyllum migahidii	Summer	16.11	40.47	26.48	13.37	10.45	17.70	9.73	1.99	28.70	3.17
		Winter	35.38	28.67	9.08	17.28	19.00	23.37	9.29	6.09	29.09	1.11
	Zilla spinosa	Summer	19.24	4.77	2.08	1.44	8.55	0.13	2.66	2.69	18.32	1.39
		Winter	34.78	8.87	4.54	2.26	45.60	4.35	19.88	5.25	15.79	0.99
	Heliotropium bacciferum	Summer	18.55	18.97	12.10	4.99	19.95	0.43	6.20	6.04	22.87	3.57
		Winter	36.38	14.50	8.32	5.49	21.85	5.44	13.16	6.79	23.94	3.56
	Rahnterium epapposum	Summer	17.38	13.43	6.24	5.21	21.85	6.62	21.39	1.25	13.51	1.05
		Winter	35.14	9.33	5.11	3.21	33.25	19.08	12.07	6.30	21.22	2.84

(40.47 g%) recorded in *Zygophyllum migahidii* plant while the lowest record was 4.77 g% in *Zilla spinosa* plant. In winter, the highest ash content (31.0 g%) found in *Moricandia sinaica* plant while the lowest value (8.87 g%) was in *Zilla spinosa* plant. It is found that *Zygophyllum migahidii* plant had high values of ash content in both summer and winter while *Zilla spinosa* plant which drops its leaves in the summer was with low values of ash content.

Higher $C1^{1-}$ content found in *Datura innoxia*, *Capparis spinosa*, *Calotropis prosera* and *Zilla spinosa* plants in winter than summer. The highest $C1^{1-}$ (26.48 g%) value recorded in summer was in *Zygophyllum migahidii* plant and lowest mean value (2.08 g%) recorded in *Zilla spinosa* plant. In winter, *Capparis spinosa* plant had the highest value (12.29 g%) and the lowest value amounted to 4.54 g% in *Zilla spinosa* plant. It is noticed that *Zilla spinosa* plant was with low $C1^{1-}$ concentrations in summer and winter.

The maximum accumulation of SO_4^{2-} was found in *Zygophyllum migahidii* plant in summer (13.37 g%) and winter (17.28 g%). The minimum accumulation of SO_4^{2-} (1.44 g% and 2.26 g%) was found in *Zilla spinosa* in summer and winter respectively.

Concentration of PO_4^{3-} increases during winter in most of the studied plant species except in *Capparis spinosa* and *Moricandia sinaica* plants. The highest mean PO_4^{3-} (65.55 mg/100g) recorded in summer in *Capparis spinosa* plant and the lowest value (8.55 mg/100g) recorded in *Zilla spinosa* plant. In winter, the highest concentration of PO_4^{3-} (63.65 mg/100g) was in *Datura innoxia* plant and the lowest (17.10 mg/100g) found in *Moricandia sinaica* plant. *Zygophyllum migahidii* plant showed low values of PO_4^{3-} (10.45 mg/100g and 19.00 mg/100g) in summer and winter respectively.

Higher Na^+ recorded in winter than in summer in all studied plant species. Despite Na^+ content in soil was more elevated in summer than in winter as a result of the evaporation process, leaving Na^+ in the surface layers of soil. It is observed that the highest Na^+ value (17.70 mg/100g) recorded in summer was in *Zygophyllum migahidii* plant and the lowest value of Na^+ (0.13 mg/100g) found in *Zilla spinosa* plant. In winter, the highest value of Na^+ (28.19 mg/100g) showed in *Moricandia sinaica* plant while the lowest value of Na^+ (4.35 mg/100g) in *Zilla spinosa* plant. Each of *Rhazya stricta* and *Cassia italica* had equal values of Na^+ (4.49 mg/100g).

K^+ in the selected various plants species considered to be high compared with the rest of other elements. Higher K^+ concentrations found in summer than in winter for most plants except *Moricandia sinaica*, *Zilla spinosa* and *Heliotropium bacciferum*. It is found that *Zygophyllum migahidii* plant had convergent values of K^+ in both seasons (9.73 mg/100g in summer and 9.29 mg/100g in winter). The highest concentration of K^+ in summer and winter found to be in *Datura innoxia* plant (24.41 mg/100g and 23.11 mg/100g, respectively). The lowest level of K^+ in summer was 2.66 mg/100g in *Zilla spinosa* plant while in winter, the lowest was 9.29 mg/100g in *Zygophyllum migahidii* plant. It is observed from our results that high K^+ content in summer within plants species developed in Old-Dir'iyah area resulted from K^+ increase in their soil, but the increase in soil was significantly lower than the increase in plants. In Jenadriah area, high K^+ level in soil was exhibited in plants. In spite of lack of K^+ in soil of Muzahimiyah area, their plants contain high K^+ level which shows the cumulative capacity of this element within the plant.

Results showed that concentration of Ca^{2+} increases in winter and decreases in the summer in all plant species under study. The highest Ca^{2+} (6.04 mg/100g) value in summer recorded in *Heliotropium bacciferum* plant and the lowest Ca^{2+} (1.25 mg/100g) recorded in *Rhanterium epapposum* plant. In winter, *Heliotropium bacciferum* plant had the highest Ca^{2+} (6.79 mg/100g) content and *Rhazya stricta* plant had the lowest Ca^{2+} (4.53 mg/100g). It is observed that Ca^{2+} values were consistent in both soil and their plants.

It is found that *Datura innoxia*, *Capparis spinosa*, *Calotropis procera*, *Zygophyllum migahidii*, *Heliotropium bacciferum* and *Rhanterium epapposum* plants contain the highest concentration of Mg^{2+} during winter. Also, *Rhazya stricta*, *Cassia italica* and *Zilla spinosa* plants recorded higher concentrations of Mg^{2+} in summer than winter. *Moricandia sinaica* plant had equal values of Mg^{2+} in both seasons (26.20 in summer and 26.17 mg/100g in winter). From our results, it is observed that Mg^{2+} is high compared to other elements in plants and it is comparable with K^+ values. Old-Dir'iyah plants contain high Mg^{2+} values in both summer and winter, although its values were low in their soil except under *Datura innoxia* plant in summer. This also applies on developing plants in Muzahimiyah area.

Results showed that the majority of plant species under study had higher Fe^{3+} concentration in summer than winter except *Moricandia sinaica* plant and *Rhanterium epapposum* plant. In summer, *Heliotropium bacciferum* plant had the highest Fe^{3+} value (3.57 mg/100g). In winter, the highest concentration of Fe^{3+} (7.49 mg/100g) was in *Moricandia sinaica* plant and the lowest value of 0.69 mg/100g in *Datura innoxia* plant.

Effect of drought on ion content of soil and plant tissue

We found that all leaf minerals accumulation was significantly correlated with soil content which affected by drought as shown in Table 4.

Table 4. Pearson correlation coefficients between plant leaves and soil mineral content in Riyadh region, Saudi Arabia

Plant leaf minerals	Soil minerals				
	Na^{+}	K^{+}	Ca^{2+}	Mg^{2+}	Fe^{3+}
Na^{+}	1.00				
K^{+}	.3844	1.00			
Ca^{2+}	.5480*	.2381	1.00		
Mg^{2+}	.7393**	.8217***	.2536	1.00	
Fe^{3+}	.3271	-.1268	-.2380	-.3561	1.00

* $p \le 0.05$; ** $p \le 0.01$; *** $p \le 0.001$

DISCUSSION

Soil properties

pH results is consistent with E1-Demerdash et al., Al-Yameni, El-Ghanem, Al-Ghanem and Alatar et al. where they found that arid and semi-arid areas have alkaline soils [9-13]. This is due to the lack of rain which is not conducive to wash lime, calcium and sodium, leading to the accumulation of these elements in the soil. High alkaline pH in summer is attributed to high evaporation rate occurs in this season as a result of high temperature, lack of organic matter and rainfall which sustain alkaline elements as well as the nature of the rocks which constituent soil. However, in winter, lower alkaline pH of top-soil than subsoil was recorded due to leaching of alkaline elements to depths by rainfall.

In summer, the accumulation of salts in the surface layer was as a result of the lack of rainfall, which is not enough to wash the total soluble salts of this layer and nominated them to the depths of the soil. Chaudhary reported that most of soils in Saudi Arabia are modern in their configuration due to the lack of moisture and constant renewal of the surface by erosion and precipitation factors. Also dissolved salts, gypsum and calcium carbonate are transmitted by the wind and added faster to the soil than the rates of their losses [14]. Low TDS contents in soil samples were obtained by E1-Demerdash et al., El-Ghanem and Al-Ghanem [9, 11, 12].

In the present study, the decline of OC is due to lack of vegetation and animal organisms in the desert environment. E1-Demerdash et al. and El-Ghanem confirmed our finding; the soils samples collected from Riyadh, Saudi Arabia have very low organic matters [9, 11]. In addition, this finding is consistent with Sharif, who found variation in the soil organic matter percentage (0.2 -0.4%) in Saudi Arabia [15].

Our results are consistent with that reported by Mujahid et al. indicating that high amount of soluble calcium carbonate in soil found in deep layers [16]. These results contrasted with findings conducted by Sharif stated that the surface layer of soil contains calcium carbonate, soluble salts even in small amounts and washed in other places to a depth of 125-150 cm, which led to the formation of very thick calcium carbonate crust (the desert crust) [15].

In the present study, lack of dissolved CO_3^{2-} in soil samples is consistent with a study carried out in Saudi Arabia and conducted by Aba Al-Khail on the soil of Unaiyza area and found that it free from dissolved CO_3^{2-} [17]. In contrast, CO_3^{2-} were found in soils samples obtained by E1-Demerdash et al. and El-Ghanem [9, 11]. Approximately similar values of dissolved HCO^{3-} at different depths in soil samples were noticed by E1-Demerdash et al. [9].

The observed means $C1^{1-}$ values were consistent with El-Ghanem and Al-Ghanem [11, 12]. High means SO_4^{2-}values is attributed to high gypsum content of the studied soils as mentioned by Chaudhary [14]. In contrast, the order of abundance of major anions was $C1^{1-} > SO_4^{2-}$ in soil obtained by Al-Ghanem [12].

Our data is confirmed by Al-Ghanem and Ibrahim who recorded low PO_4^{3-} values of soil samples in Saudi Arabia. Also, they found that lack of PO_4^{3-} adversely affect plants and lead to a lack of soil fertility [12, 18]. Hu and Schmidhalter revealed that the uptake of PO_4^{3-} by crop plants is reduced in dry-soil conditions [1].

Similar high Ca^{2+} means in soil samples were obtained by E1-Demerdash et al. and Al-Ghanem [9,12]. Sharif and Mohammadayn stated that the geological structure of Saudi Arabia is sedimentary rocks [15, 19]. Chaudhary found that the highest Ca^{2+} values recorded in the surface layers while high values of Ca^{2+} were also recorded in the deeper layers of the soil under some plants [14]. In summer, Ca^{2+} found to be in the surface layer due to water evaporation from the soil surface.

Lower Mg^{2+} concentrations in soil samples than those of the present study were found by E1-Demerdash et al. (Mg^{2+} =2.2-3.1 mg/100g) and Al-Ghanem; (Mg^{2+} =3.4-8.5 mg/100g) [9, 12].

Approximate similar K^{+} results were obtained by Al-Ghanem (K^{+}=8.6-10.4 mg/100g) [12]. Lower results were reported by E1-Demerdash et al. (K^{+}=0.1-0.7 mg/100g) and El-Ghanem (K^{+}=0.2-0.7 mg/100g) [9, 11].

Lower Na^{+} levels in soil samples than those of the current study were demonstrated by El-Ghanem [11]. Higher results were obtained by E1-Demerdash et al. [9].

Lack of Fe^{3+} in soil under study is due to it is not being a key component in the original rock. In contradiction with our study, Nafe detected high Fe^{3+} content in soils due to mixing of Fe^{3+} with soil by wind precipitation coming from western regions, which represents a composition of igneous rocks, especially wind severe Riyadh that is high-speed and bearing a large amount of suspended matter [20].

Previous results indicated that there is variation in the soil composition from mineral elements among various areas, which due to the topography of the land where desert soil formed from several sedimentary layers and wind erosion is a large factor in the soil layers composition. Also, it depends on the difference in the needs for different elements by each plant.

Plant leaves content

High total carbonate content in plants species developed in Muzahimiyah followed by Jenadriah and Old-Dir'iyah were correspond with its concentration in their soils. Our results agree with E1-Demerdash et al. and Altesan studies on some plants in Saudi Arabia [9, 21].

Ash content is a good indicator of the ion content within the plant tissue. This finding is consistent with Altesan who reported high ash content in *Zygophyllum qatarense* developed in Saudi Arabia [21]. Also, our results confirmed by a study on desert plants in Egypt carried out by Emad El-Deen which found that *Zilla spinosa* had low values of ash content [22].

High $C1^{1-}$content found in plant species developed in Muzahimiyah area was consistent with high $C1^{1-}$content in their soils. *Capparis spinosa* recorded high levels of $C1^{1-}$ in its leaves despite the lack of $C1^{1-}$ content in its soil. It is considered a cumulative characteristic for this plant. This finding agrees with Jobbágy and Jackson where high $C1^{1-}$ levels were found in the studied plants [2]. In addition, the order of abundance of major anions was $C1^{1-} > SO_4^{2-}$ in plant tissue obtained by Hussain and Alquwaizany [23].

High SO_4^{2-} concentrations in soil and plant species (*Zygophyllum migahidii* and *Moricandia sinaica*) developed in Muzahimiyah area were compatible. In Jenadriah area, low SO_4^{2-} in soil reflected in the uptake of their plants. Our SO_4^{2-} results were in agreement with Jobbágy and Jackson, Hussain and Alquwaizany and Han et al. [2, 23, 24]. Similar high PO_4^{3-} results were obtained in plant tissues conducted by Jobbágy and Jackson and Han et al. [2, 24].

Similar Na^{+} levels in plant species were obtained by E1-Demerdash et al. and Hussain and Alquwaizany [9,23]. Lower Na^{+} concentrations in plant leaves than our results were obtained by Jobbágy and Jackson [2].

There is variation in K^{+} values among summer and winter for different plants and this is due to the difference in the growing season of each plant. High K^{+} concentrations in plant tissues were recorded by Jobbágy and Jackson, Hussain and Alquwaizany and Han et al. [2, 23, 24]. However, low K^{+} concentrations in vegetation obtained by E1-Demerdash et al. [9].

Ca^{2+} more increase in winter than in summer in all the studied plants. This agrees with Aba Al-Khail study on desert plants [17]. Higher Ca^{2+} levels in plant species than those in the present study were reported by Jobbágy and Jackson, E1-Demerdash et al. and Han et al. [2, 9, 24]. In contrast, lower Ca^{2+} in plant species than our data obtained by Hussain and Alquwaizany [23].

Similar Mg^{2+} levels in plant tissues were obtained by E1-Demerdash et al. and Han et al. [9, 24]. However, Jobbágy and Jackson and Hussain and Alquwaizany revealed low Mg^{2+} levels in different plant tissues [2, 23].

Fe^{3+} content in plants varies among seasons depending on growth seasons. Similar Fe^{3+} content in plant leaves were obtained by Han et al. [24].

Drought effect on soil and plant mineral

Soil chemical attributes (e.g. pH and mineral nutrient availability) are critical to plant growth and thus affect leaf mineral patterns [24].

Han et al. demonstrated positive correlations between plant leaf and soil mineral contents for most minerals [24]. This finding is consistent with our results.

Ahmed and Girgis studied adaptive responses of plants at different environments in Sinai, Egypt and revealed that desert plants depend on accumulation of organic compounds to resist drought and ionic minerals help halophytes for osmotic adjustments [25]. Rains and waizel suggested that Na^{+} plays an important role in maintaining water balance [26, 27]. Abo-Sitta and Al-Taisan reported that plants increase their drought-resistant by electrolytic and non-electrolytic materials accumulation with increase juiciness in plants [28]. Moreover, Ford and Wilson noticed the accumulation of Na^{+} in *Panicum trichoglume* plant and K^{+} in *Cenchrus ciliaris* and *Heteropogon contortus* plants. Accumulation of these ions largely accounted for the osmotic adjustments [29]. Emad El- Deen found that more accumulation of Ca^{2+}, Mg^{2+} and $C1^{1-}$ in drought-tolerant plants grow in sunrise than shade plants grow in sunset under the same environment [22]. Abd El-Rahman et al. and El-Monayeri et al. demonstrated that with deficiency in soil moisture the majority of accumulated ions (K^{+}, Na^{+}, Ca^{2+}, Mg^{2+}, and $C1^{1-}$) increases and a minority (PO_4^{3-} and Fe^{3+}) decrease. The sum of total ions accumulated in the plant tissues increases with decrease in soil moisture and rise in moisture stress [30, 31]. This is consistent with our results.

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