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Research Article

A Study on the Soil-Plant Interactions of Some *Cistus* L. Species Distributed in West Anatolia

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Abstract: This study was undertaken with the aim of examining the soil-plant interactions of *Cistus creticus* L. and *Cistus salviifolius* L. in West Anatolia. The soil analysis data showed that these plants grow in different kinds of soils with sandy-clayey-loam, clayey-loam and loamy texture. The soils in general are not saline but are moderately and slightly alkaline, being rich in nitrogen and having a low level of phosphorus and potassium. They are unaffected by the calcium carbonate content in soils. A negative relation was observed in *C. creticus* after regression analysis between plant calcium and soil phosphorus, plant calcium and soil salts, but a positive relation between plant calcium and soil calcium carbonate. In *C. salviifolius*, there was a positive relation between plant calcium and soil pH.

Key Words: *Cistus creticus*, *Cistus salviifolius*, Autecology.

Batı Anadolu'da Yayılış Gösteren Bazı *Cistus* L. Türlerinin Toprak-Bitki İlişkileri Üzerine Bir Çalışma

Özet: Bu çalışma, Batı Anadolu'da yayılış göstern *Cistus creticus* L. ve *Cistus salviifolius* L.'un toprak-bitki ilişkilerini ortaya koymak amacıyla yapılmıştır. Bu iki türün, kumlu-killi-tınlı, kumlu-tınlı ve tınlı; tuzsuz, hafif ve orta alkali; azotça zengin; fosfor ve potasyum bakımından eksik, kireç bakımından ise her türlü toprakta yetiştiği tespit edilmiştir. Yapılan regresyon analizlerinde *C. creticus*'da; toprak fosforu ile bitki kalsiyumu, toprak tuzu ile bitki kalsiyumu arasında negatif bir ilişki, toprak kireci ile bitki kalsiyumu arasında pozitif bir ilişki; *C. salviifolius*'da toprak pH ile bitki kalsiyumu arasında pozitif bir ilişki gözlenmiştir.

Anahtar Sözcükler: *Cistus creticus*, *Cistus salviifolius*, Otekoloji.

Introduction

The *Cistaceae* family includes 8 genera with 175 species distributed in the temperate zone of the northern hemisphere, especially in Mediterranean climates. Out of these taxa, the woody and perennial genus *Cistus* L. has 16 species, 5 of which are distributed in Turkey. These are *Cistus creticus* L., *C. salviifolius* L., *C. parviflorus* L., *C. monspeliensis* L. and *C. laurifolius* L. (Davis, 1965). Although *C. parviifolius* and *C. monspeliensis* are macchia elements, it was reported that they are less frequently found in West Anatolian macchia plant societies, and *C. laurifolius* is a sub-Mediterranean element (Rikli, 1948). On the other hand, *C. creticus* and *C. salviifolius* are reported as dominant elements of West Anatolian macchia and phrygana plant societies (Peşmen, 1971). Therefore, among these five *Cistus* species, *C. creticus* and *C. salviifolius* were investigated. Both are regarded as dominant elements of macchia and phrygana and such groups are named *Cistus*-macchia. However, some investigators call these low-macchia, being dominated by *Cistus* and *Erica* (Mert, 1973). *C. creticus* is distributed all along the coastal belt of the Turkish Mediterranean phytogeographical region, as well as some enclaves along the Black Sea coast. These species adorn habitats with their purple flowers from late March till June, extending from sea level up to an altitude of 1000 m (Davis, 1965; Mert, 1973).

C. salviifolius shows a wider distribution. It extends towards the inner parts of Anatolia up to the Submediterranean and Irano-Turanian regions (Mert, 1973). The flowers of *C. salviifolius* are white. Flowering starts in early April and fruits ripen from late July to early

August. It is distributed among the macchia from sea level to 500 m in altitude (Davis, 1965).

The resin obtained from *C. creticus* is volatile and smells like etheric oil. It is used for the treatment of dysentery and used as expectorant. The leaves of *C. salviifolius* are used as tea and for the treatment of cancer (Baytop, 1991; Zeybek & Zeybek, 1994). Dye substances obtained from aerial parts of the *Cistus* species, especially fruit cupules and leaves, give a yellow-brown colour and its shades. These are widely used in areas where the hand-made kilim and carpet industry is present (Eyüboğlu *et al.*, 1983; Anonymous, 1991).

In view of the economic importance of the *Cistus* species mentioned above, an attempt has been made to present soil-plant interactions of *C. creticus* and *C. salviifolius* here.

Materials and Methods

The specimens of *C. creticus* and *C. salviifolius* were collected from different localities in West Anatolia and identified taxonomically with the help of the Flora of Turkey and the East Aegean Islands (Davis, 1965). These localities are listed below. All of the specimens are deposited at the personal herbarium with a Doğan code.

C. creticus

İzmir; 1. Menderes, Yeniköy, Doğan 335, 2. Seferihisar, Akkum, Doğan 336; 3. Çeşmealtı, Güvendik, Doğan 337; 4. Mordoğan, Doğan 338; 5. Çeşme, Boyalık, Doğan 339; 6. Beydağ, Alakeçili, Doğan 340; Manisa; 7. Akhisar, Doğan 341; 8. Gördes, Doğan 342; 9. Alaşehir, Derbent, Doğan 343; Aydın; 10. Kuşadası, Doğan 344; 11. Didim, Akbük, Doğan 345; 12. Ortaklar, Doğan 346; Denizli; 13. Güney, Doğan 347; Balıkesir; 14. Sındırgı, Doğan 348; 15. Biga, Doğan 349; Muğla; 16. Milas, Bafa lake, Doğan 350; 17. Bodrum, Gündoğan, Doğan 351; 18. Fethiye, Doğan 352; 19. Marmaris, Ilıcalar, Doğan 353.

C. salviifolius

İzmir; 1. Gümüldür, Ahmetbeyli, Doğan 354; 2. Çeşme, Alaçatı, Doğan 355; 3. Seferihisar, Akkum, Doğan 356; 4. Çeşmealtı, Güvendik, Doğan 357; 5. Mordoğan, Doğan 358; 6. Selçuk, Doğan 359; Aydın; 7. Ortaklar, Doğan 360; 8. Bafa, Doğan 361; 9. Didim, Doğan 362; 10. Söke, Doğan 363; 11. Kuşadası, Doğan 364; Muğla; 12. Milas, Gökçek, Doğan 365; 13. Fethiye, Doğan 366; 14. Marmaris, Ilıcalar, Doğan 367; 15. Bodrum, Ortakent, Doğan 368; 16. Köyceğiz, Doğan 369.

The soil samples were collected from the same localities from where plants were collected during the flowering period. The litter on the soil was removed and soils were dug out from 0-30 cm at random. About 500 g of each sample was placed in polyethylene bags and brought to the laboratory. These were air dried, ground, passed through a 2 mm sieve and analysed for different physico-chemical characteristics. Texture, total soluble salts, calcium carbonate and pH were determined according to the methods outlined in Öztürk *et al.* (1997). Total nitrogen was determined according to Bremner (1965), using the Kjeldahl method and total phosphorus by the Bingham (1949) method. Total potassium was determined by using a flame photometer, following the method outlined by Pratt (1965).

Aerial parts (stem, leaves and flowers) of the plants were collected the localities given above in July, dried at 80°C in an air-blown oven for 24 hours, ground with a commercial blender and prepared for analysis. Total nitrogen, phosphorus, potassium and calcium were determined following the methods given by Bremner (1965), Lott *et al.* (1965), and Kacar (1972). Statistical correlations between pH, total soluble salts, calcium carbonate, nitrogen, phosphorus and potassium in soils and nitrogen, phosphorus, potassium and calcium in the plants were examined. Regression curves and correlation coefficients were obtained with the help of statistical program given by İkiz *et al.* (1996) and McClave *et al.* (1998).

Results and Discussion

The natural habitat of our study area, where Mediterranean climatic conditions are dominant, and in which winters are warm and rainy, and summers are dry and hot, are covered by sclerophyllous trees and macchia species which need less water and high temperatures (Temuçin, 1993). Investigation of Mediterranean climatic conditions and drought levels were performed according to Emberger (Akman, 1990). In Emberger's climate classification, the following climatic elements are used by taking into consideration that plants are active between certain temperatures: the mean minimum temperature for the coldest month (m), the mean maximum temperature for the hottest month (M), annual precipitation (P) and pluviothermic quotient values (Q). Meteorological data obtained from local meteorology stations of seven cities in our study area were applied to Emberger's formula. These results with respect to the cities are as follows: Çanakkale (P: 628.5 mm, M: 30.2ºC, m: 2.8ºC, Q: 78.2), Balıkesir (P: 594.8 mm, M: 30.7ºC, m: 1.5ºC, Q: 70.4), Manisa (P: 748.3 mm, M: 34.4ºC, m: 2.9ºC, Q: 81.4), İzmir (P: 695.2 mm, M: 32.7ºC, m: 5.5ºC, Q: 87), Aydın (P: 670.1 mm, M: 35.1ºC, m: 4.2ºC, Q: 73), Denizli (P: 351.7 mm, M: 33.3ºC, m: 1.9ºC, Q: 60.4) and Muğla (P: 1209.2 mm, M: 32.8ºC, m: 1.6ºC, Q: 133.5) (Akman, 1990). From these results, according to the pluviothermic quotient value (Q) and the annual precipitation value (P), which identified the general drought level, the areas were *C. creticus* and *C. salviifolius* are distributed are classified into humid (Muğla), sub-humid (Balıkesir, Manisa, İzmir, Aydın, Çanakkale) and semi-arid (Denizli) bioclimatic zones, among six Mediterranean bioclimates (Akman, 1990). However, both species are densely distributed in sub-humid Mediterranean bioclimatic zones. According to the mean minimum temperature for the coldest month in the Mediterranean bioclimatic zone, it is understood that *C. creticus* and *C. salviifolius* are distributed in cool zone (Çanakkale, Balıkesir, Manisa, Denizli, Muğla) and temperate (İzmir, Aydın) zone variants. However, both species are densely distributed in the cool zone. It was claimed that in the area where the mean minimum temperature for the coldest month is below zero, the development of macchie elements is almost impossible (Temuçin, 1993), and our results show a parallelism with this claim.

In the study area, different geological and lithological structures can be seen. Generally in the area, Palaeozoic metamorphic schist-gneiss, mica schist; alluvion, quaternary; Neogene marl, sandstone, soft limestone; Mesozoic limestone, flysh and ophiolite structures are dominant. Sometimes, Palaeozoic clayey schist can be found. Soil structures in the region are determined by lithological characteristics. Generally in the region, red Mediterranean soil–Alfisol, brown forest soil–inceptisol, and alluvial soil are dominant. In addition, very little stony–pebbly soils and rendzinas can be found (Atalay, 1994; Atalay, 1997).

The investigation of the relationship between parent material–soil and vegetation in the region showed that soils were eroded away and low-nutrient soils remained on the siliceous parent material. In these types of regions, short shrubs consisting of phrygana or garigue are widespread. On the tuffites, which have volcano-sedimentary characteristics, the poorest settings from the number of species and vegetation density are formed from these formations. The volcanites found in the study area are andesitic-dacitic volcanic stones, agglomerates, tuffs and granites. Volcano-sedimentary formations are layers of neogene lake sediments which originated from tuffs and agglomerates, as well as clay-stone, sandstone and marl layers. Andesites are impermeable and extremely resistant to dissolving. Since they contain feldspar, the dissolved products are generally clayey. However, in some places where erosion occurs rocks appear. In regosols and lithosols, some elements between the size of sand and gravel are present. In these fields, because the pedogenical process is extremely slow, the soil is transported in a short time by erosion. Very weak vegetation is found on this soil. In contrast to these findings, a lithobiome, affected by the bedrock, occurs (Çukur, 1995; Atalay, 1997; Atalay *et al.*, 1998).

Phrygana elements are widespread in fields where parent material appears with very little soil on which plant growth is extremely difficult. They grow on volcanic intro-structural neogene deposits. Their vegetation is distributed on every kind of soil, especially on red Mediterranean, rendzina and other calcareous soils. They are also seen on volcanic tuffs and andesites. Phrygana elements in the study area, because of the dense destruction, seem to form stable vegetation on agglomerate, neogene clayey-calcareous and volcanic tuffs (Atalay *et al.*, 1998).

Physical Analysis of the Soils

The results of the physical analysis of the *C. creticus* and *C. salviifolius* soils collected from the study area during the flowering and fruiting period are given in Tables 1 and 2. *C. creticus* grows on clayey-loam (31.50%), sandy-clayey-loam (26.30%), sandy-loam (15.75%), and loamy (26.30%) soils. *C. salviifolius* prefers clayey-loam (37.50%), sandy-clayey-loam (12.50%), sandy-loam (25%) and loamy (25%) soils. Both species prefer clayey-loam soils, as reported by other researchers (Vardar & Ahmet, 1965; Kutbay & Kılınç, 1995).

The pH of the soils supporting *C. creticus* and *C. salviifolius* varies between 6.80 and 7.92, and 7.19 and

Table 1. Physical and chemical analysis of the soils of *C. creticus*.

Loc.	Sand %	Clay %	Silt %	Texture	pH	Salts %	$CaCO_3$ %	N %	P %	K %
1	46.16	29.84	24	Sandy-clayey-loam	7.55	0.045	1.243	0.058	0.00004	0.025
2	41.44	30.56	28	Clayey-loam	7.67	0.038	2.840	0.340	0.00020	0.062
3	51.44	26.56	22	Sandy-clayey-loam	7.65	0.047	12.350	0.142	0.00004	0.074
4	59.44	20.56	20	Sandy-clayey-loam	7.64	0.032	39.200	0.065	0.00002	0.046
5	53.44	24.56	22	Sandy-clayey-loam	7.77	0.030	11.420	0.126	0.00004	0.076
6	40.16	29.84	30	Clayey-loam	7.77	0.044	7.030	0.086	0.00010	0.015
7	70.44	23.56	6	Sandy-clayey-loam	7.45	0.045	0.502	0.045	0.00011	0.023
8	38.44	35.56	26	Clayey-loam	7.58	0.055	37.460	0.047	0.00015	0.025
9	76.44	9.56	14	Sandy-loam	7.75	0.037	4.250	0.065	0.00046	0.039
10	47.44	18.86	34	Loam	7.35	0.065	1.890	0.214	0.00280	0.035
11	48.44	19.56	32	Loam	7.21	0.043	2.385	0.654	0.00014	0.065
12	56.44	19.56	24	Sandy-loam	7.75	0.037	27.260	0.263	0.00011	0.024
13	43.44	24.56	32	Loam	7.85	0.035	39.750	0.055	0.00002	0.031
14	41.16.	26.84	32	Loam	7.15	0.043	0.865	0.104	0.00250	0.067
15	33.16	32.84	34	Clayey-loam	6.80	0.120	0.120	0.034	0.00380	0.030
16	68.44	13.56	18	Sandy-loam	7.92	0.0037	16.700	0.048	0.00011	0.020
17	49.16	18.84	32	Loam	7.35	0.067	1.360	0.320	0.00180	0.019
18	35.16	36.84	28	Clayey-loam	7.42	0.089	1.600	0.073	0.00050	0.010
19	31.44	30.56	38	Clayey-loam	7.56	0.053	1.240	0.343	0.00011	0.033
				Min.	6.80	0.0037	0.120	0.0340	0.00002	0.010
				Max.	7.92	0.1200	39.750	0.6440	0.00380	0.076
				Mean	7.54	0.0488	11.024	0.16221	0.00069	0.03789
				S.D.	0.277	0.0244	14.159	0.15995	0.00114	0.02089
				S.E.	0.063	0.0056	0.248	0.03670	0.00026	0.00479

Min.: Minimum, Max.: Maximum, S.D.: Standard Deviation, S.E.: Standard Error

Table 2. Physical and chemical analysis of the soils of *C. salviifolius*.

Loc.	Sand %	Clay %	Silt %	Texture	pH	Salts %	$CaCO_3$ %	N %	P %	K %
1	45.44	30.56	24	Sandy-clayey-loam	7.45	0.031	1.218	0.066	0.00002	0.023
2	34.16	39.84	26	Clayey-loam	7.40	0.055	2.865	0.898	0.00120	0.047
3	41.44	30.56	28	Clayey-loam	7.67	0.038	2.840	0.340	0.00020	0.062
4	57.44	16.56	26	Sandy-loam	7.84	0.042	34.240	0.115	0.00012	0.051
5	58.44	23.56	18	Sandy-clayey-loam	7.64	0.032	39.200	0.065	0.00002	0.046
6	70.16	9.84	20	Sandy-loam	7.40	0.041	30.080	0.158	0.00064	0.039
7	60.44	15.56	24	Sandy-loam	7.80	0.033	26.400	0.265	0.00015	0.029
8	67.16	14.84	18	Sandy-loam	7.92	0.037	16.700	0.048	0.00011	0.023
9	40.16	29.84	30	Clayey-loam	7.19	0.036	2.640	0.624	0.00014	0.064
10	45.44	24.56	30	Loam	7.60	0.047	18.240	0.223	0.00080	0.032
11	45.44	22.56	32	Loam	7.74	0.030	38.250	0.092	0.00006	0.037
12	34.16	37.84	28	Clayey-loam	7.46	0.218	18.910	0.086	0.00410	0.058
13	39.16	30.84	30	Clayey-loam	7.42	0.089	1.600	0.073	0.00050	0.010
14	31.44	31.56	38	Clayey-loam	7.56	0.053	1.240	0.343	0.00011	0.033
15	43.16	20.84	36	Loam	7.40	0.065	1.420	0.320	0.00180	0.019
16	47.16	18.84	34	Loam	7.75	0.058	4.53	0.064	0.00040	0.004
				Min.	7.19	0.030	1.218	0.048	0.00002	0.004
				Max.	7.92	0.218	39.20	0.898	0.00410	0.064
				Mean	7.64	0.05656	13.08581	0.23685	0.00065	0.03606
				S.D.	0.3339	0.04576	13.88690	0.23562	0.00104	0.01789
				S.E.	0.08335	0.01144	3.47172	0.06890	0.00026	0.00447

7.92 respectively (Tables 1 and 2). Soil analysis data show that 15.78% of soils supporting *C. creticus* are neutral, 73.68% are slightly alkaline and 10.52% are moderately alkaline; for the soils of *C. salviifolius*, 6.15% are neutral, 75% are slightly alkaline and 18.75% are moderately alkaline (Jackson, 1958). A preference for slightly to moderately alkaline soils resembles the behaviour of *Pistacia lentiscus* L. (*Anacardiaceae*) distributed in the same region (Öztürk & Ataç, 1982). However, *C. creticus* has been reported to flourish on neutral soils as well (Kutbay & Kılınç, 1995).

The calcium carbonate content of the soils of *C. creticus* and *C. salviifolius* varies from 0.120-39.750% and 0.03-0.218% (Tables 1 and 2). Accordingly, 47.36% of *C. creticus* soils are poor, 10.52% are moderate, 5.26% are rich and 36.84% are very rich in calcium carbonate. Among *C. salviifolius* soils, 25% are poor, 25% are calcareous, and 50% are very rich in calcium carbonate (Scheffer & Schactschabel, 1956). In contrast, *C. creticus* has been reported to prefer non-calcareous soils (Kutbay & Kılınç, 1995).

The salinity values of *C. creticus* soils vary from 0.18 to 0.90% (Table 1). The soils are non-saline in general. Salinity values for *C. salviifolius* soils vary from 0.03 to 0.218% (Table 2), 93.75% being non-saline and 6.25% slightly saline (Anonymous, 1951). A comparison of our data with those of other researchers (Vardar & Ahmet, 1965; Öztürk & Ataç, 1982; Kutbay & Kılınç, 1995; Mert *et al.*, 1996) reveals that *C. creticus* and the other species (*Myrtus communis* L. *(Myrtaceae), P. lentiscus* and *Spartium junceum* L. *(Fabaceae)* distributed in the same region occupy non-saline soils.

Chemical Analysis of the Soils

The nitrogen content of *C. creticus* soils varies from 0.034 to 0.065% (Table 1). Accordingly, 21.05% of the soils are poor, 31.58% are moderate, 15.79% are sufficient and 31.58% rich in nitrogen. Nitrogen content of *C. salviifolius* soils lies between 0.048 to 0.898% (Table 2), with 6.25% being poor, 37.50% moderate, 6.25% sufficient and 50% rich in nitrogen (Loue, 1968). However, according to Kutbay and Kılıç (1995), *C. creticus* prefers rich nitrogenous soils.

The phosphorus content of soils supporting *C. creticus* and *C. salviifolius* is given Tables 1 and 2. Some 94.75% of the *C. creticus* soils are very deficient and 5.25% deficient, 93.75% of *C. salviifolius* soils are very deficient and 6.25% deficient in phosphorus (Bingham, 1949). Similar findings are reported by other investigators (Mert *et al.*, 1996; Kutbay, 1997).

The soil potassium values for *C. creticus* and *C. salviifolius* are presented in Tables 1 and 2. Potassium values were 0.0100 to 0.0760% and 0.004 to 0.064%. The soils of both species are deficient in potassium (Pizer, 1967). Our results concur with those of earlier workers (Mert *et al.*, 1996, Kutbay, 1997).

Chemical Analysis of the Plants

Chemical analysis of the aerial parts of *C. creticus* and *C. salviifolius* shows that nitrogen content was 0.882-1.316%, and 0.644-1.232% respectively (Tables 3 and 4). The values of nitrogen were generally 0.2-6% (Kacar, 1972), as such our results lie within normal limits.

Phosphorus values were 0.18-0.90% (Table 3) and 0.078-0.98% (Table 4). Limit values given for phosphorus are 0.01-1.0% (Johnson & Ulrich, 1959), and these fully cover our values too.

The values of potassium content were 0.53-1.05% and 0.62-2.00% in *C. creticus* and *C. salviifolius* (Tables 3 and 4). This range fully coincides with the general values of 0.20-11.0% (Kacar, 1972).

The calcium content of these species was 0.320-2.240% (Table 3) and 0.4-1.71% (Table 4) respectively,

Table 3. Chemical analysis of the plants of *C. creticus*.

Loc.	N %	P %	K %	Ca %
1	1.246	0.70	0.89	0.72
2	1.022	0.30	0.65	1.08
3	0.980	0.46	0.89	0.68
4	1.316	0.64	1.02	2.24
5	1.092	0.56	0.81	1.00
6	1.050	0.74	0.71	0.56
7	1.008	0.38	0.68	0.64
8	0.924	0.40	0.55	0.56
9	1.036	0.48	0.87	0.56
10	1.288	0.90	1.05	0.56
11	1.064	0.54	0.83	1.44
12	0.938	0.32	0.53	0.68
13	0.924	0.50	0.69	1.24
14	1.162	0.54	0.74	0.52
15	1.050	0.18	0.68	0.32
16	1.008	0.50	0.63	0.92
17	0.882	0.18	1.05	0.64
18	1.176	0.54	0.78	0.80
19	0.910	0.40	0.79	0.80
Min.	0.882	0.18	0.53	0.32
Max.	1.316	0.90	1.05	2.24
Mean	1.05663	0.48632	0.78105	0.84
S.D.	0.12843	0.18160	0.15430	0.43492
S.E.	0.02946	0.04166	0.03540	0.09978

Table 4. Chemical analysis of the plants of *C. salviifolius*.

Loc.	N %	P %	K %	Ca %
1	0.798	0.280	1.30	0.85
2	0.644	0.078	1.30	0.70
3	0.854	0.100	1.70	0.69
4	0.896	0.800	0.89	0.48
5	0.952	0.201	1.80	1.70
6	0.783	0.480	0.66	0.80
7	1.078	0.980	0.66	0.80
8	1.223	0.214	1.76	0.89
9	1.166	0.960	1.24	0.65
10	0.986	0.820	1.72	1.59
11	0.882	0.760	1.71	0.40
12	1.232	0.124	2.00	0.98
13	0.840	0.340	1.60	0.88
14	0.764	0.740	0.62	0.49
15	0.882	0.920	0.88	0.64
16	0.783	0.860	0.74	0.52
Min.	0.644	0.078	0.62	0.40
Max.	1.232	0.980	2.00	1.71
Mean	0.92269	0.55106	1.22375	0.816088
S.D.	0.17264	0.35719	0.44829	0.36553
S.E.	0.04316	0.08930	0.12207	0.09138

which lies within the adequate limit of 0.93% (Chapman, 1967).

Statistical Evaluation of the Soil and Plant Analysis Results

The statistical evaluation of the results between the nitrogen, phosphorus, potassium, pH, total soluble salts and calcium carbonate content of the soils and nitrogen, phosphorus, potassium and calcium content of the plants showed that four relevant correlations are visible in the regression analysis; two of these are negative and two are positive correlations. The latter were observed between potassium and calcium, and calcium carbonate and calcium; the former between total soluble salts and calcium, and pH and calcium. No other relevant correlations were obtained. Regression curves and correlations coefficients showed that negative correlations exist between soil phosphorus and plant calcium (r^2: 0.20, r: 0.44) (Table 5, Figure 1); and total soluble soil salts and plant calcium (r^2: 0.17, r: 0.41) in *C. creticus* (Table 6, Fig. 2). However, a positive

Table 5. Regression analysis of soil phosphorus and plant calcium content in *C. creticus*.

Linear Fit

Summary of Fit

Rsquare	0.201784
Root Mean Square Error	0.399836
Mean of Response	0.84
Observations (or Sum Wgts)	19

Analysis of Variance

Source	Df	Sum of Squares	Mean Square	F Ratio
Model	1	0.6870349	0.687035	4.2975
Error	17	2.7177651	0.159869	Prob>F
C Total	18	3.4048000		0.0537

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>ltl
Intercept	0.9576535	0.10787	8.88	0.0000
Soil Phosphorus	-171.2962	82.6304	-2.07	0.0537

Bivariate

Variable	Mean	Std Dev	Correlation	Signif. Prob	Number
Soil Phosphorus	0.000687	0.001141	-0.4492	0.0537	19
Plant Calcium	0.84	0.43492			

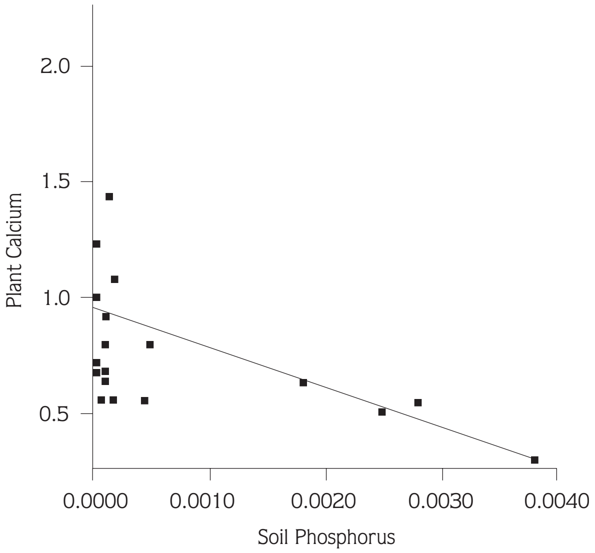

Figure 1. Regression analysis graph of soil phosphorus and plant calcium in *C. creticus*.

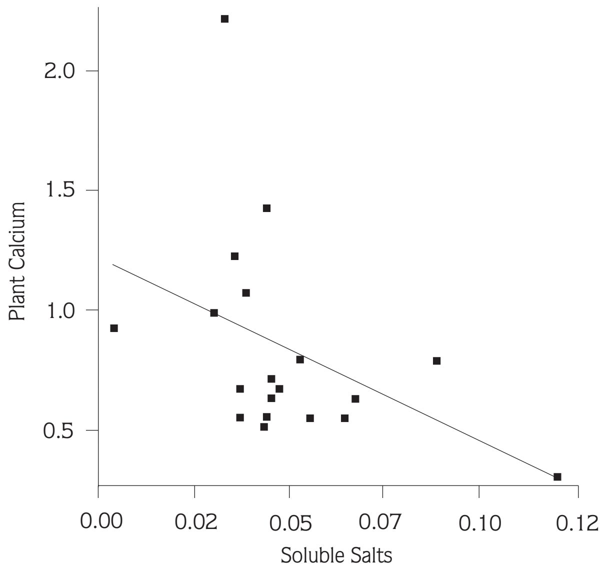

Figure 2. Regression analysis graph of total soluble soil salts and plant calcium in *C. creticus*.

Table 6. Regression analysis of total soluble soil salts and plant calcium content in *C. creticus*.

Linear Fit

Summary of Fit

Rsquare	0.177857
Root Mean Square Error	0.405784
Mean of Response	0.84
Observations (or Sum Wgts)	19

Analysis of Variance

Source	Df	Sum of Squares	Mean Square	F Ratio
Model	1	0.6055680	0.605568	3.6777
Error	17	2.7992320	0.164661	Prob>F
C Total	18	3.4048000		0.0721

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>ltl
Intercept	1.2074951	0.21305	6.57	0.0000
Soil Salts	-7.518474	3.92052	-1.92	0.0721

Bivariate

Variable	Mean	Std Dev	Correlation	Signif. Prob	Number
Soil Salts	0.048879	0.024396	-0.42173	0.0721	19
Plant Calcium	0.84	0.43492			

correlation exists between soil calcium carbonate and plant calcium (r^2: 0.24, r: 0.48) in *C. creticus* (Table 7, Fig. 3). In *C. salviifolius*, a positive correlation between soil pH and plant calcium (r^2: 0.22, r: 0.46) was obtained (Table 8, Fig. 4). Since the probability values of the total soluble salts in soil and plant calcium in *C. creticus* correlations were less than 0.05, the correlation coefficients and models were significant (İkiz *et al.*, 1996; McClave *et al.*, 1998). Other correlations were very close to 0.05, but with a lower coefficient. The correlation exponents (r) show that relationships are weak. r^2 expresses, in terms of percentage, changes in the plant caused by the variables in the soil. The fact that our findings for these percentages are low shows that the plant is malnourished by the infertile soil and that these affect the soil-plant relationship negatively. Other results showed neither positive nor negative correlations.

In the related literature it was reported that there is an important relationship between soil phosphorus and plant calcium and between soil calcium and plant calcium

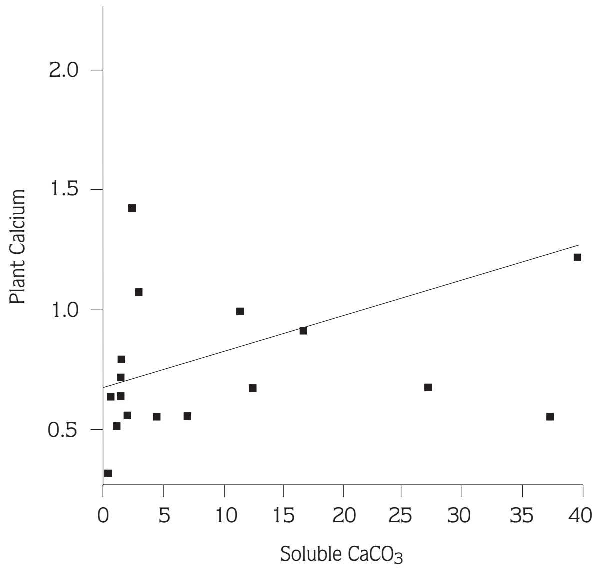

Figure 3. Regression analysis graph of soil calcium carbonate and plant calcium in *C. creticus*.

Table 7. Regression analysis of soil calcium carbonate and plant calcium content in *C. creticus*.

Linear Fit

Summary of Fit

Rsquare	0.242322
Root Mean Square Error	0.38955
Mean of Response	0.84
Observations (or Sum Wgts)	19

Analysis of Variance

Source	Df	Sum of Squares	Mean Square	F Ratio
Model	1	0.8250579	0.825058	5.4370
Error	17	2.5797421	0.151750	Prob>F
C Total	18	3.4048000		0.0323

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>Itl
Intercept	0.6733103	0.11444	5.88	0.0000
Soil $CaCO_3$	0.01512	0.00648	2.33	0.0323

Bivariate

Variable	Mean	Std Dev	Correlation	Signif. Prob	Number
Soil $CaCO_3$	11.02447	14.15973	0.492262	0.0323	19
Plant Calcium	0.84	0.43492			

Table 8. Regression analysis of soil pH and plant calcium content in *C. salviifolius*.

Linear Fit

Summary of Fit

Rsquare	0.221711
Root Mean Square Error	0.333788
Mean of Response	0.816875
Observations (or Sum Wgts)	16

Analysis of Variance

Source	Df	Sum of Squares	Mean Square	F Ratio
Model	1	0.4443405	0.444341	3.9882
Error	14	1.5598032	0.111415	Prob>F
C Total	15	2.0041437		0.0656

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>ltl
Intercept	-3.127312	1.97678	-1.58	0.1360
Soil pH	0.5162548	0.25851	2.00	0.0656

Bivariate

Variable	Mean	Std Dev	Correlation	Signif. Prob	Number
Soil pH	7.64	0.333387	0.470862	0.0656	16
Plant Calcium	0.816875	0.365526			

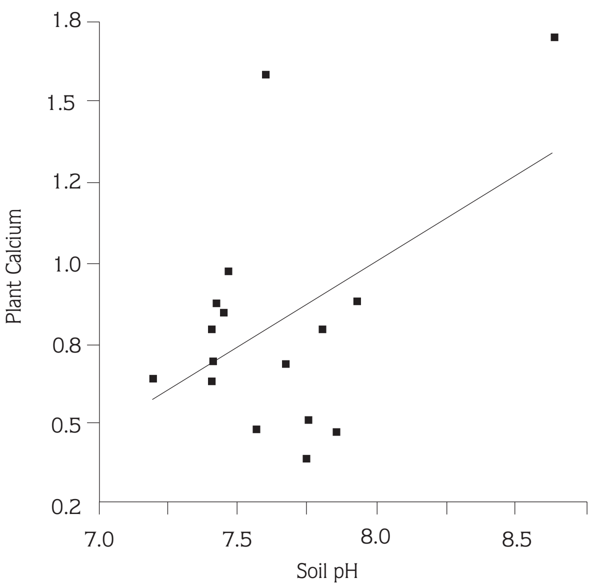

Figure 4. Regression analysis graph of soil pH and plant calcium in *C. salviifolius*.

(Walker & Mason, 1960; Bould, 1966). In our study, not as many statistically significant correlations between soil and plant were found. The reason could be that mineral substances in the field were washed away and, as a result, mineral substances were transported to the lower layers (Atalay, 1977). Being thin, the soil layer caused plants' roots to not reach sufficient depths in the soils and, as a result, this caused the plants to be weak. For example, nitrogen in the soil was reported to become dense between 25 and 75 cm depending on the thickness of the soil layer (Atalay, 1977). A plant unable to reach this depth cannot absorb sufficient minerals from the soil. Lack of statistical relations between other elements and relatively low-level correlation coefficients of the determined relations showed that plants in the soil have difficulties in absorbing adequate amounts of minerals. Since some of our plants are phrygana members, our findings showed a parallelism with Çukur's (1995) findings. It was discovered in a study carried out on different species that the deficiency of minerals in the soil negatively affects plant growth (Başlar & Mert, 1998).

During our field excursions and observations in West Anatolia, it was found that *C. creticus* and *C. salviifolius* are distributed in a mixed form with other *Cistus* species together with *Arbutus unedo* L., *A. andrachne* L. (*Ericaceae*), *Juniperus* L. (*Cupresseceae*), *Quercus coccifera* L. (*Fagaceae*) and *Pinus brutia* Ten. (*Pinaceae*) (Davis, 1965).

An analysis of soil and plant samples collected from 35 different localities in West Anatolia revealed that the soils preferred by these two species are clayey-loam, sandy-clayey-loam, sandy-loam, and loamy in texture, non-saline in salt content, and slightly to moderately alkaline. They are unaffected by calcium carbonate in soils but flourish on soils rich in nitrogen, containing inadequate levels of phosphorus and potassium. Plant analysis showed that the calcium content was low, but nitrogen, phosphorus and potassium were within normal levels in both species. A negative relation was observed in *C. creticus* after regression analysis between plant calcium and soil phosphorus, plant calcium and soil salts, but a positive relation between plant calcium and soil calcium carbonate. In *C. salviifolius* there was a positive relation between plant calcium and soil pH.

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