Tr. J. of Botany
23 (1999) 33-44

Research Article

Studies on the Ecology of *Chrozophora tinctoria* L. and *Rubia tinctorum* L. in Western Anatolia

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Received: 21.01.1998
Accepted: 09.07.1998

Abstract: This study was carried out to determine the autecological and economic importance of *Chrozophora tinctoria* L. (*Euphorbiaceae*) and *Rubia tinctorum* L. (*Rubiaceae*) distributed in western Anatolia. A Physical and chemical analysis was performed on the soils where these plants grow and a chemical analysis of the plants was also carried out. The results obtained were assessed using regression analysis. It was found that both of the plants generally grow on loam and clayey-loam; neutral to slightly alkaline soils which are both poor and rich in calcium carbonate; slightly saline; moderately rich, rich and very rich in organic matter; rich and moderately rich in phosphorus; and high and very high in potassium content.

Key Words: Autecology, Dye plant, *Rubia tinctorum* L., *Chrozophora tinctoria* L.

Batı Anadolu'da Yayılış Gösteren *Chrozophora tinctoria* L. ve *Rubia tinctorum* L. Türlerinin Ekolojisi Üzerinde Bir Araştırma

Özet: Bu araştırmada Batı Anadoluda yayılış gösteren *Chrozophora tinctoria* L. (*Euphorbiaceae*) ve *Rubia tinctorum* L. (*Rubiaceae*)'un otoekolojisi ve ekonomik önemini ortaya koymak amacı ile yapılmıştır. Yaşadıkları toprakların fiziksel ve kimyasal analizleri ve bitkilerin kimyasal analizleri yapıldı. Elde edilen sonuçlar regrasyon analiz yöntemi ile değerlendirildi. Her iki bitkininde genellikle tınlı ve killi-tınlı bünyeli, nötr ve hafif alkali topraklarda yetiştiği, daha çok kireçce fakir ve zengin toprakları tercih ettiği, tuzluluk etkisinin çok az olduğu, organik madde bakımından orta, zengin ve çok zengin, fosfor bakımından orta ve zengin, potasyum bakımından ise yüksek ve çok yüksek toprakları tercih ettikleri saptandı.

Anahtar Sözcükler: Otoekoloji, Boya Bitkileri, Kök Boya, Akbaş Otu.

Introduction

Turkey has a rich flora because of its geographical position and climate. Autecological studies on economically important plants are of great importance in understanding growth conditions and effective use of these plants. Accordingly, *Rubia tinctorum* L. and *Chrozophora tinctoria* L. were chosen for this study. Studies carried out in Turkey on the autecology of some taxa include studies of *Myrtus communis* L. (1), *Ceratonia siliqua* L. (2), *Mentha* L. (3), *Inula viscosa* (L.). Aiton (4), *Cistus laurifolius* L. and *Rumex obtusifoluis* L. subsp. *subalpinus* Schur. (5) and *Spartium junceum* L. (6). Nearly 150 kinds of plant are used in the production of natural dyes in (7). There has been a great increase in the number of autecological studies of plants used in natural dye production (8). *R. tinctorum* and *C. tinctoria,* which grow widely in western Anatolia, the are of this study, were used as the research material of this study because of their value in dye production and also because of their medicinal importance. It is known that substances used in dyes are obtained from the roots and rhizomes of *R. tinctorum* (9). It has also been reported that a grey-colored dye is obtained from the fresh fruits of *R. tinctorum* (10) and that the dye substance produced from the underground suckers of this plant includes pseudo-purparin, rubiadin, minjistin, alizarin and purparin (11, 12). In addition, it is known that this plant is used as a diuretic (13), as a treatment for stones (14) and as fodder (15). The other plant chosen as study material, *C. tinctora,* grows as a ruderal plant in plantation areas. This plant belongs to the family *Euphorbiaceae* and is called the "turnsole" plant. Dye substances can be produced from any of its organs (16). The plant which is known as "Akbaş" (White head) in some parts of Anatolia is an

annual type of this plant (17). In the light of the facts cited above and because of the side effects of synthetic dyes, autecological studies of *R. tinctorum* and *C. tinctoria* were carried out to determine their potential as dye substances. The results of this study should be helpful in the cultivation of these plants for the use of the textile industry in Turkey.

Materials and Methods

The specimens of *R. tinctorum* and *C. tinctoria* were collected from different localities in western Anatolia. These localities are listed below. All of the specimens are deposited at the herbarium of the Biology Dep., Faculty of Buca Education, University of Dokuz Eylül.

Chrozophora tinctoria L.

MANİSA: 1. Akhisar entrance (DEBB 293), 2. Süleymanlı village exit (DEBB 294), 3. Kırkağaç (DEBB 295), 4. Soma; Turgutalp (DEBB 296), 5. Kula (DEBB 297), 6. Turgutlu - Avşar (DEBB 298); BALIKESİR: 7. Savaştepe, Karaçam (DEBB 299), 8. Ayvalık; Altınova (DEBB 300), 9. Burhaniye; Karaağaç (DEBB 301), 10. Edremit (DEBB 302), 11. Bandırma; Aksakal (DEBB 303), 12. Bandırma; Erdek, Gelinönü (DEBB 304), 13. Balıkesir; Susurluk (DEBB 305); ÇANAKKALE: 14. Lapseki (DEBB 306); İZMİR: 15. Kınık (DEBB 307), 16. Bergama Bakırçay (DEBB 308), 17. Kemalpaşa (DEBB 309), 18. Beydağ; Çiftlik (DEBB 310), 19. Tire; Gökçe (DEBB 311), 20. Torbalı; Aslanlar (DEBB 312), 21. Menemen, Türkeli (DEBB 313), 22. Aliağa, Kalabak (DEBB 314), 23. Aliağa; Çaltıdere(DEBB 315), 24. Foça; Bağarası (DEBB 316), 25. Urla - Çeşmealtı (DEBB 317), 26. Çeşme; Ilıca (DEBB 318), 27. Çamlık-Aydın (DEBB 319); MUĞLA: 28. Milas-Selimiye (DEBB 320), 29. Bodrum-Turgutreis (DEBB 321), 30. Yatağan; Maden (DEBB 322), 31. Ula (DEBB 323), 32. Ula-Ataköy (DEBB 324), 33. Köyceğiz; Doğuşbelen (DEBB 325), 34. Fethiye; Hisarönü (DEBB 326); DENİZLİ: 35. Acıpayam; Darıveren (DEBB 327), 36. Kale; Kavakdede (DEBB 328), 37. Buldan (DEBB 329); AYDIN: 38. Kuşadası (DEBB 330), 39. Söke (DEBB 331), 40. Sultanhisar (DEBB 332), 41. Koçarlı (DEBB 333), 42. Germencik-Ortaklar (DEBB 334).

Rubia tinctorum L.

MANİSA: 1. Üçpınar (DEBB 335), 2. Beydere (DEBB 336), 3. Akhisar (DEBB 337), 4. Kırkağaç (DEBB 338), 5. Soma (DEBB 339), 6. Turgutlu; Avşar (DEBB 340), 7. Salihli, Tayvan (DEBB 341); BALIKESİR: 8. Savaştepe (DEBB 342), 9. Ayvalık: Altınova (DEBB 343), 10. Burhaniye: Karaağaç (DEBB 344), 11. Manyas: Salurköy (DEBB 345), 12. Bandırma: Erdek (DEBB 346), 13. Susurluk (DEBB 347), 14. Bigadiç: (DEBB 348), 15. Sındırgı: Kumluca (DEBB 349); ÇANAKKALE: 16. Ayvacık: Süleymanköy (DEBB 350), 17. Ezine (DEBB 351), 18. Bayramiç: (DEBB 352), 19. Çan: Hurmaköy (DEBB 353), 20. Lapseki (DEBB 354), 21. Biga: Hamdiköy (DEBB 355); İZMİR: 22. Kınık: (DEBB 356), 23. Bergama: Bakırçay (DEBB 357), 24. Menemen: Türkeli (DEBB 358), 25. Aliağa: Çaltıdere (DEBB 359), 26. Foça: Bağarası (DEBB 360), 27. Urla: Çeşmealtı (DEBB 361); MUĞLA: 28. Milas, Ağaçlıhöyük (DEBB 362), 29. Bodrum: Turgutreis (DEBB 363), 30. Yatağan: Bozarmut (DEBB 364), 31. Fethiye: Seke; (DEBB 365), DENİZLİ: 32. Çameli: Kınıkyeri (DEBB 366), 33. Acıpayam (DEBB 367), 34. Kale: Kavakdede (DEBB 368), 35. Tavas: Medet (DEBB 369), 36. Çardak: Beylerli (DEBB 370), 37. Çal: Denizler (DEBB 371), 38. Baklan: (DEBB 372), 39. Çivril: Menteş (DEBB 373); AYDIN: 40. Nazilli: Durasallı (DEBB 374), 41. Koçarlı (DEBB 375).

The soil samples were collected from the localites above between the months of July and August. The soil samples were collected, after cleaning of the litter on the soil, put into polyethylene bags and taken immediately to the laboratory. They were left under laboratory conditions and air-dried. The dried soil samples were ground, passed through a 2 mm sieve and subjected to analysis. The texture, water holding capacity, total soluble salts, calcium carbonate ($CaCO_3$) and organic matter were determined according to the method of Öztürk et al. (18). The pH values were determined using soil samples saturated with distilled water (19). The N, P and K contents of the determined according to the method outlined in Kjeldahl, described by Hewetson (20). The total phosphorus was determined with a spectro photometer at a wavelength of 436 nm. The total potassium was determined with a flame photometer. The aboveground parts (stem, leaves and flowers) of the plants were collected from different localities in the flowering and fruiting period (July-August), dried at 80°C in an air-blowing oven for 24 hours, ground with a commercial blender and prepared for analysis. Nitrogen (N), Phosphorus (P), Potassium (K), Calcium (Ca), Sodium (Na), Manganese (Mn), Zinc (Zn) and Copper (Cu) were determined according to the methods given in detail by Kacar (21). Positive and negative correlation between organic matter, pH, P, K, total soluble salts, $CaCO_3$ in soils and N, P, K, Ca, Na, Mn, Zn and Cu in plants were examined. Regression curves and correlation coefficients were obtained statistically from the analysis results by means of Jmp software according to the method of Akkaya and Hasgür (22).

Results and Discussion

The underground parts of *R. tinctorum* have been used for obtaining "Turkish Scarlet" dye, which is famous around the world. Turkey was the source of up to two third of the world's madder root production. We selected the underground parts of *R. tinctorum* and the aboveground parts of *C. tinctoria* due to their dye characteristics. These two plants grow in the western Anatolia region and are used for obtaining tones of red.

Physical Analysis of the Soils

Table 1 shows that the soils on which *C. tinctoria* grows have pH values of 6.28-7.90. Of soils taken from 42 different sites, 33.33% were neutral, 61.90% slightly alkaline and 2.38% moderately alkaline, according to the scale given by Öztürk et al. (18). In Table 2, the pH of the soils where *R. tinctorum* grows are given and the values vary between 6.22 and 7.98. Using the scale given by Öztürk et al. (18), of soils from 41 different places, 2.44% are weakly acidic, 31.72% neutral, 63.44% slightly alkaline and 2.4% are moderately alkaline. *Inula graveolens* (L.) Desf., *Pistacia lentiscus* L., and *Asphodelus aestivus* Brot (23, 24, 25) grow under similar conditions, in neutral and slightly alkaline soils, as do sugar cane, onion and sunflower. *C. tinctoria* also prefers these soils because of their neutral and slightly alkaline character (26), as does the *Chrozophora* genus (27).

Table 1 shows that *C. tinctoria* grows on loamy (45.23%), clayey-loam (42.85%) and turfy (11.90%) soils. The soils in which *R. tinctorum* grows, (Table 2) are loamy (29.28%) clayey-loam (43.88%) and turfy (26.84%). *I. graveolens* and *A. aestivus* (23, 25) also grow in loamy and clayey-loam soils. Other studies of *C. tinctoria* report that this plant grows in loamy and clayey-loam soils (26). The soil texture of *C. tinctoria* is reported to be loamy (27). The results of the present study were consistent with this data. Table 1 shows that the $CaCO_3$ values of the soils of *C. tinctoria* vary from 0 to 30%. It can be seen that 40.47% of these soils are poor in $CaCO_3$, 19.04% are calcareous, 16.16% are rich in $CaCO_3$ and 23.80% are very rich in $CaCO_3$. Table 2 shows that the $CaCO_3$ values of the soils of *R. tinctorum* vary from 0 to 29.78%. 31.76% are very calcareous, 19.52% rich in $CaCO_3$, 10.51% calcerous in $CaCO_3$ while 29.28% werepoor. *C. tinctoria* and *R. tinctorum* grow on soils both rich and poor in $CaCO_3$ (26, 27, 28). It can be seen that the water holding capacities of 54.76% of soils of *C. tinctoria* and 75.60% of soils of *R. tinctorum* are higher than 50% (Tables 1 and 2). The water holding capacities of *R. tinctorum* are in agreement with our findings (28). In general both plants prefer wet soils. The total salt content of the soils where *C. tinctoria* and *R. tinctorum* grow show that for *C. tinctoria* 95.23% of the soils are non-saline and 4.76 slightly saline. The salinity values of the *R. tinctorum* soils vary from 0.017 to 0.406%, 78.08% being non-saline, 19.52% slightly saline and 2.39% moderately saline. It has been reported that *R. tinctorum* and *Capparis ovata* L., *C. spinosa* L., plants prefer non-saline soils (28, 29).

Chemical Analysis of the Soils

The results of the chemical analysis of the *C. tinctoria* soils collected from the study areas during the flowering and fruiting period are given in Table. The organic matter content of the soils varies from 0.31 to 6.88%, 11.90% being very poor, 23.80% poor, 11.90% moderately rich, 28.60% rich ad 23.80% very rich in organic matter. The results of the chemical analysis of the soils of *R. tinctorum* collected from the study area during the flowering and fruiting period are given in Table 2. The Organic matter of these soils varies from 0.17 to 8.04%. 12.2% of these soils are very poor, 14.60% poor, 24.4% moderately rich, 29.28% rich and 19.52% very rich in organic matter. *C. tinctoria* and *R. tinctorum* prefer moderately rich and very rich soils. It is reported that *I. viscosa,* like *C. tinctoria,* prefers moderate, rich and very rich soils (4, 24). The nitrogen content of *C. tinctoria* soils varies from 0.389 to 3.094%. 95.23% were rich, 2.3% sufficient and 2.3% moderate in nitrogen content. The nitrogen content of *R. tinctorum* soils varies from 0.497 to 2.898%, with 92.68% rich in nitrogen, 4.87% sufficient and 2.43% moderate. These sepcies prefer nitrogenous soils. It has been observed that *C. ovata* and *C. spinosa* growing in West Anatolia also prefer nitrogen-rich soils (29). The phosphorous contents of the *C. tinctoria* soil samples are given in Table 1. 21.44% of the soils are poor, with 33.33% moderate and 45.23% rich in phosphorus. The phosphorus contents of the *R. tinctorum* soil samples are shown in Table 2. 4.84% of the soils are poor, 14.64% moderate and 80.52% rich in phosphorus. *C. tinctoria* prefers soils which are moderate to rich in phosphorus and *R. tinctorum* soils rich in phosphorus. It has been reported that *C. ovata* and *C. spinosa* plants also prefer soils rich in phosphorus (29).

The soil potassium values for *C. tinctoria* are presented in Table 1. These vary from 0.002 to 0.187%. 7.17% of the soils are deficient, 45.23% low, 90% sufficient, 19.04% high and 16.66% very high in potassium. The potassium contents of the soils are also shown in Table 2. The soil potassium values for *R. tinctorum* vary from 0.005 to 0.093%. 7.32% of the

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

Locality	M.W.H.C. %	Textural Classification	pH	Total soluble salts(%)	$CaCO_3$ (%)	Ogr, mat, (%)	N (%)	P (%)	K (%)
1	60.18	loamy	7.83	0.141	9.80	3.56	0.960	0.0099	0.086
2	56.240	clayey-loamy	7.70	0.104	20.54	1.27	0.270	0.0013	0.014
3	48.25	loamy	7.90	0.067	26.39	2.28	1.265	0.0043	0.017
4	46.68	turbier	7.46	0.053	23.38	5.80	0.408	0.0038	0.018
5	48.101	clayey-loamy	7.52	0.087	1.05	3.00	0.100	0.0069	0.077
6	36.89	loamy	7.13	0.050	0.97	1.50	1.406	0.0076	0.012
7	35.56	loamy	7.59	0.107	30.33	2.40	1.214	0.00003	0.034
8	64.73	clayey-loamy	7.52	0.157	23.20	2.28	0.244	0.0013	0.031
9	57.15	clayey-loamy	7.77	0.102	5.94	1.10	0.148	0.0015	0.035
10	38.19	loamy	7.72	0.033	4.83	0.31	2.320	0.0037	0.010
11	54.73	clayey-loamy	7.49	0.097	3.57	2.76	2.112	0.00003	0.025
12	59.03	clayey-loamy	7.65	0.111	23.97	1.48	1.402	0.00003	0.014
13	58.95	clayey-loamy	7.35	0.120	21.04	3.24	0.150	0.0001	0.040
14	52.41	clayey-loamy	6.70	0.113	-	2.20	0.058	0.0036	0.032
15	58.24	turbier	7.28	0.133	9.29	5.80	1.130	0.0032	0.093
16	36.67	loamy	6.75	0.020	-	0.57	0.680	0.0014	0.017
17	40.95	turbier	7.70	0.028	6.22	5.52	0.254	0.0005	0.010
18	54.90	clayey-loamy	7.77	0.044	7.03	1.72	1.160	0.0001	0.013
19	54.22	clayey-loamy	7.30	0.074	0.97	3.44	0.254	0.0033	0.025
20	48.30	loamy	7.01	0.073	1.37	0.80	1.142	0.0017	0.018
21	51.49	loamy	7.30	0.082	1.53	1.84	0.220	0.0033	0.069
22	43.68	loamy	6.28	0.079	-	3.92	0.302	0.0021	0.049
23	53.06	clayey-loamy	7.50	0.089	2.34	3.00	0.332	0.0043	0.082
24	60.11	clayey-loamy	6.90	0.206	-	2.72	0.806	0.0029	0.086
25	42.90	loamy	7.47	0.067	26.09	1.96	1.404	0.0031	0.031
26	56.39	clayey-loamy	7.55	0.119	4.69	1.90	0.906	0.0012	0.055
27	60.09	clayey-loamy	7.42	0.053	2.87	1.66	1.560	0.0020	0.012
28	37.43	loamy	7.22	0.105	3.19	1.12	1.564	0.0037	0.002
29	48.967	loamy	7.58	0.108	2.07	1.36	0.282	0.0014	0.009
30	61.13	clayey-loamy	7.50	0.114	22.58	3.00	0.540	0.0009	0.039
31	41.99	loamy	7.07	0.063	1.20	2.74	0.584	0.0017	0.013
32	71.13	turbier	7.46	0.147	6.14	6.88	0.560	0.0023	0.008
33	48.07	loamy	7.88	0.068	4.95	2.88	0.360	0.0004	0.003
34	59.34	clayey-loamy	7.42	0.089	1.60	1.04	1.330	0.0005	0.011
35	58.38	clayey-loamy	7.28	0.085	11.09	1.21	0.604	0.0011	0.028
36	58.99	clayey-loamy	7.27	0.070	4.79	1.92	0.508	0.0023	0.022
37	41.33	loamy	7.60	0.019	2.00	0.98	0.544	0.0005	0.0044
38	55.70	turbier	7.45	0.068	1.94	4.28	1.786	0.0027	0.031
39	47.30	loamy	7.23	0.060	2.15	3.24	0.218	0.0020	0.007
40	35.76	loamy	7.48	0.057	0.64	0.63	0.222	0.0011	0.007
41	41.555	loamy	7.47	0.070	4.71	1.24	0.460	0.0019	0.013
42	51.478	loamy	7.24	0.080	0.96	1.04	0.440	0.0035	0.020
min	35.56		6.28	0.017	0	0.31	0.058	0.00003	0.002
max	71.13		7.90	0.206	30.33	6.88	2.32	0.0099	0.093
mean	50.89		7.39	0.083	7.79	2.45	0.76	0.0023	0.029
S.D.	8.82		0.32	0.038	9.03	1.50	0.585	0.0020	0.024

Table 2. Physical and chemical analysis of the soils of *R. tinctorum*.

Locality	M.W.H.C. %	Textural Classification	pH	Total soluble salts(%)	$CaCO_3$ (%)	Organic matter(%)	N (%)	P (%)	K (%)
1	58.04	clayey-loamy	7.60	0.179	2.93	3.68	0.892	0.0035	0.091
2	69.54	clayey-loamy	7.73	0.203	5.45	1.58	0.104	0.0029	0.041
3	52.54	loamy	7.83	0.141	9.80	3.56	0.960	0.0099	0.086
4	52.15	loamy	7.77	0.093	29.78	1.45	1.264	0.0025	0.031
5	47.74	turbier	7.58	0.065	23.70	5.52	1.406	0.0036	0.017
6	68.48	clayey-loamy	7.73	0.406	3.07	1.44	1.304	0.0047	0.023
7	62.69	clayey-loamy	7.51	0.127	6.71	3.12	1.408	0.0054	0.075
8	60.42	turbier	7.30	0.121	23.66	4.00	0.840	0.0015	0.034
9	63.20	clayey-loamy	7.52	0.157	23.20	2.28	0.250	0.0013	0.031
10	59.48	clayey-loamy	7.77	0.102	5.94	1.10	0.158	0.0015	0.035
11	69.43	turbier	7.13	0.237	2.62	6.44	1.462	0.0094	0.083
12	60.04	clayey-loamy	7.65	0.111	23.97	1.48	0.732	0.0000	0.014
13	38.15	loamy	7.68	0.025	2.22	0.17	0.446	0.0000	0.021
14	71.73	clayey-loamy	7.72	0.219	1.99	1.36	1.368	0.0015	0.072
15	52.33	loamy	7.05	0.045	0.97	2.08	1.440	0.0029	0.077
16	64.03	clayey-loamy	7.40	0.187	2.14	1.84	0.606	0.0088	0.074
17	41.51	clayey-loamy	7.58	0.109	4.51	2.64	0.708	0.0055	0.058
18	60.30	turbier	7.53	0.122	0.71	5.80	1.208	0.0033	0.065
19	61.05	turbier	6.22	0.102	-	4.00	1.362	0.0102	0.074
20	51.48	clayey-loamy	6.70	0.113	-	2.20	0.060	0.0036	0.032
21	43.80	loamy	7.55	0.032	21.50	0.68	1.228	0.0021	0.005
22	59.00	turbier	7.28	0.133	9.29	5.80	0.150	0.0032	0.093
23	36.88	loamy	6.75	0.020	-	0.57	1.165	0.0014	0.017
24	54.80	loamy	7.30	0.082	1.53	1.84	0.230	0.0033	0.069
25	53.61	clayey-loamy	7.50	0.089	2.34	3.00	0.300	0.0043	0.082
26	42.77	loamy	7.52	0.142	0.48	3.92	0.448	0.0050	0.069
27	62.24	loamy	7.47	0.067	26.09	1.96	1.420	0.0031	0.031
28	62.22	clayey-loamy	7.46	0.218	18.91	2.40	0.242	0.0041	0.058
29	57.03	turbier	7.17	0.048	1.24	5.44	0.288	0.0033	0.036
30	53.06	turbier	7.38	0.017	8.78	4.28	0.248	0.0043	0.042
31	75.21	turbier	7.52	0.075	4.39	8.04	1.340	0.0078	0.069
32	60.13	turbier	7.50	0.115	18.03	6.32	0.420	0.0044	0.065
33	62.31	clayey-loamy	7.31	0.074	4.79	2.51	0.272	0.0051	0.069
34	65.13	clayey-loamy	7.27	0.070	4.79	1.92	0.420	0.0023	0.022
35	65.20	clayey-loamy	7.40	0.055	12.76	2.52	0.216	0.0074	0.069
36	49.85	turbier	7.62	0.028	4.83	7.84	1.248	0.0033	0.011
37	60.00	clayey-loamy	7.46	0.053	17.56	2.59	0.162	0.0060	0.060
38	59.94	clayey-loamy	7.63	0.085	14.34	2.60	0.202	0.0060	0.069
39	41.92	loamy	7.69	0.046	7.99	1.49	1.154	0.0150	0.045
40	41.53	loamy	7.98	0.045	0.48	0.31	0.280	0.0065	0.044
41	45.40	loamy	7.34	0.085	13.57	0.72	1.660	0.0017	0.021
min	36.88		6.22	0.020	0	0.17	0.060	0	0.005
max	75.21		7.98	0.406	29.78	8.04	1.660	0.0150	0.093
mean	56.50		7.44	0.108	11.30	2.98	0.757	0.0043	0.050
S.D.	9.43		0.32	0.073	16.05	1.99	0.518	0.0036	0.024

Table 3. Physical and chemical analysis of the soils of *C. tinctoria*.

Locality	N (%)	P (%)	K (%)	Ca (%)	Na (%)	Mn (ppm)	Zn (ppm)	Cu (ppm)
1	2.142	0.232	2.160	2.040	0.12	50	50.2	12
2	2.156	0.252	2.040	2.340	0.06	60	46.2	8
3	2.148	0.212	2.120	2.680	0.12	65	48.4	12
4	2.536	0.256	2.340	2.410	0.08	40	55.3	20
5	1.838	0.268	2.620	2.680	0.10	80	66.8	16
6	2.118	0.252	1.420	2.410	0.012	45	62.4	12
7	2.460	0.196	2.110	2.920	0.06	60	53.4	8
8	1.806	0.180	1.760	2.640	0.08	45	59.4	12
9	1.720	0.220	2.120	2.310	0.14	80	63.4	20
10	1.934	0.268	2.320	2.480	0.06	85	76.8	16
11	1.726	0.300	1.840	2.400	0.24	90	46.2	12
12	2.716	0.160	1.060	2.120	0.08	70	48.4	8
13	2.860	0.224	1.320	1.860	0.10	70	57.6	8
14	3.002	0.212	2.520	2.000	0.14	60	60.4	16
15	1.820	0.220	1.700	2.460	0.08	50	52.8	12
16	2.128	0.264	1.820	2.520	0.08	80	56.8	12
17	2.506	0.256	2.060	2.620	0.24	55	70.6	8
18	2.002	0.100	2.180	2.240	0.06	85	82.3	20
19	1.610	0.180	1.640	2.860	0.12	55	42.8	16
20	2.450	0.268	1.260	2.460	0.08	75	60.7	12
21	1.890	0.300	1.860	2.400	0.06	60	39.6	12
22	1.932	0.224	1.600	2.940	0.06	65	59.4	12
23	2.320	0.220	1.080	2.420	0.12	50	66.3	8
24	2.700	0.268	1.540	1.860	0.24	45	55.6	20
25	1.792	0.160	1.560	2.340	0.06	40	63.4	16
26	2.716	0.204	1.380	3.000	0.12	60	46.2	12
27	1.604	0.252	2.020	2.080	0.08	75	46.4	8
28	2.340	0.252	1.240	2.580	0.10	100	46.2	16
29	2.280	0.212	1.700	2.580	0.24	75	60.7	16
30	1.804	0.244	2.160	2.460	0.06	70	83.2	12
31	2.800	0.252	1.760	1.920	0.08	100	68.6	20
32	3.094	0.252	1.040	2.460	0.10	35	59.4	16
33	2.520	0.252	1.360	1.620	0.14	70	34.3	16
34	2.534	0.256	1.380	1.680	0.10	90	85.8	20
35	2.506	0.256	1.620	2.220	0.06	55	39.6	20
36	2.002	0.196	1.820	2.760	0.06	75	50.2	12
37	1.610	0.100	2.700	2.510	0.06	35	26.4	8
38	2.198	0.192	1.680	2.280	0.06	40	60.7	16
39	2.144	0.204	1.720	1.740	0.08	65	41.4	12
40	2.380	0.224	1.680	2.760	0.06	125	68.6	20
41	2.310	0.244	1.520	1.800	0.10	70	55.4	16
42	2.002	0.244	1.420	2.830	0.06	70	44.9	8
min	1.604	0.100	1.060	1.620	0.012	40	26.4	8
max	3.002	0.300	2.700	3.000	0.24	125	85.8	20
mean	2.218	0.226	2.143	2.361	0.09	66.16	56.2	13.7
S.D.	0.389	0.042	2.385	0.352	0.05	18.88	12.76	4.1

Table 4. Chemical analysis of the plants of *R. tinctorum*.

Locality	N (%)	P (%)	K (%)	Ca (%)	Na (%)	Mn (ppm)	Zn (ppm)	Cu (ppm)
1	1.078	0.032	2.00	2.70	0.06	50	34.3	16
2	2.898	0.264	3.24	1.17	0.12	80	55.4	20
3	2.310	0.180	3.36	2.58	0.22	70	72.6	20
4	1.610	0.148	2.64	1.92	0.06	50	44.9	12
5	1.680	0.224	2.46	2.16	0.06	60	52.8	16
6	2.400	0.084	3.22	2.78	0.34	65	38.8	16
7	2.110	0.110	2.54	2.66	0.10	80	94.9	20
8	1.640	0.106	2.68	1.34	0.08	60	83.2	20
9	1.302	0.050	3.02	1.92	0.20	55	76.4	12
10	1.804	0.074	2.92	2.44	0.28	75	70.8	12
11	2.400	0.194	1.98	2.64	0.14	115	62.2	16
12	2.780	0.158	3.00	1.88	0.32	85	44.2	12
13	1.090	0.202	2.16	1.28	0.26	195	66.9	20
14	2.310	0.206	3.12	1.20	0.18	110	72.4	20
15	1.720	0.242	1.78	2.08	0.06	135	84.9	12
16	1.220	0.272	2.94	2.54	0.36	190	45.5	16
17	2.440	0.094	2.74	1.78	0.24	140	46.8	12
18	1.098	0.154	3.22	1.90	0.10	165	78.4	16
19	2.114	0.264	1.84	2.46	0.12	120	80.6	8
20	2.660	0.220	2.34	1.24	0.26	180	48.2	12
21	2.402	0.232	2.58	2.04	0.32	175	62.6	16
22	2.492	0.208	2.88	2.22	0.12	50	47.5	12
23	1.778	0.156	1.80	2.64	0.30	80	46.2	16
24	2.226	0.224	2.34	1.92	0.22	100	76.6	16
25	1.638	0.104	3.06	2.10	0.16	85	39.6	16
26	2.562	0.188	2.04	2.36	0.34	105	68.9	20
27	1.652	0.204	2.40	1.68	0.06	50	39.6	12
28	1.736	0.192	2.88	1.68	0.10	90	59.4	16
29	2.100	0.276	2.00	2.28	0.26	60	95	12
30	1.176	0.056	2.28	2.04	0.06	80	76.6	20
31	1.582	0.282	3.30	2.66	0.06	145	70.4	16
32	2.688	0.072	2.50	1.84	0.18	170	90.8	12
33	2.142	0.268	2.04	2.10	0.10	75	55.4	20
34	1.540	0.060	3.18	1.50	0.06	60	58.1	20
35	1.834	0.228	2.46	1.98	0.06	60	102.9	12
36	2.366	0.264	2.70	1.14	0.08	50	34.3	12
37	2.310	0.160	2.54	2.76	0.06	75	34.3	16
38	1.330	0.060	2.22	2.80	0.10	200	73.9	20
39	2.310	0.212	2.52	1.86	0.26	100	63.4	16
40	2.002	0.208	3.36	1.38	0.36	60	44.9	12
41	1.986	0.096	2.72	1.18	0.32	70	77.3	8
min	1.078	0.032	1.78	1.14	0.06	50	34.3	8
max	2.898	0.282	3.36	2.80	0.36	200	102.9	20
mean	1.963	0.187	2.61	2.02	0.17	98	63.6	14.78
S.D.	0.497	0.113	0.45	0.50	0.10	45.5	18.09	4.64

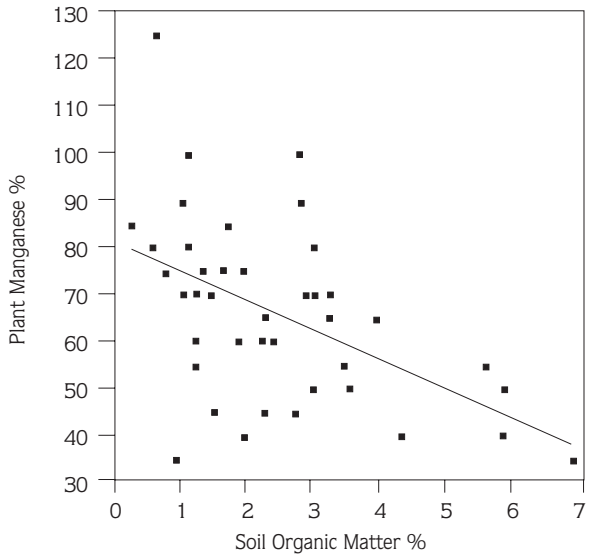

Figure 1. Regression analysis of soil organic matter and plant mangese content in *C. tinctoria.*

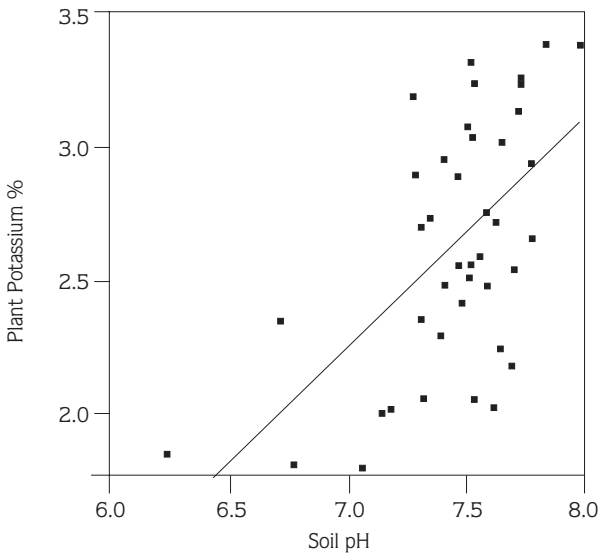

Figure 2. Regression analysis of soil pH and plant potassium content in *R. tinctorum.*

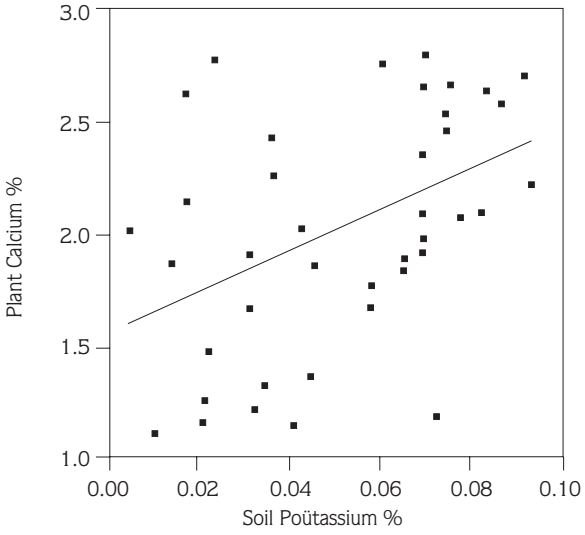

Figure 3. Regression analysis of soil potassium and plant calcium content in *R. tinctorum.*

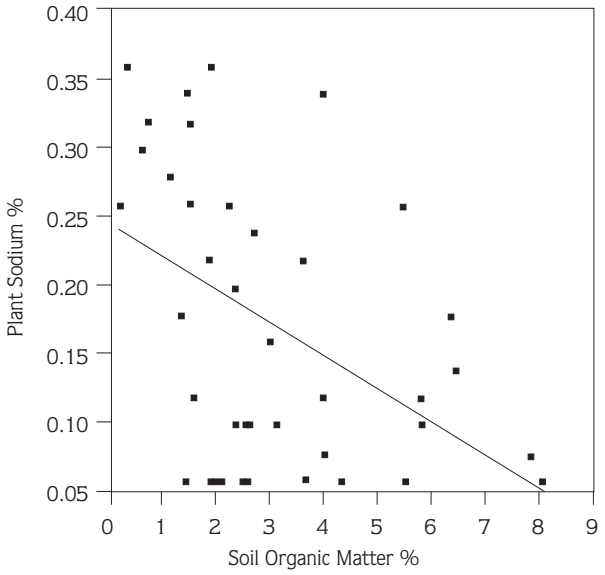

Figure 4. Regression analysis of soil organic matter and plant sodium content in *R. tinctorum.*

soils are deficient, 4.88% low, 9.76% sufficient, 17.08% high and 61% very high in potassium. It can be seen that *C. tinctoria* and *R. tinctorum* prefer very rich potassium soils. It has been reported that *C. rottleri* species also prefer soils rich in potassium (27).

Chemical Analysis of the Plants

The results of the chemical analysis of the *C. tinctoria* plants collected in the flowering season are given in Table 1. The total nitrogen, phosphorus, potassium, calcium, sodium, manganese, zinc and copper contents vary within the ranges: 1.610-3.094%, 0.100-0.300%, 1.040-2.620%, 1.620-2.920%, 0.06-0.24%, 35-125, 26.4-85.8 and 8-20 respectively in terms of dry weight. Table 4 shows the chemical analysis results for *R. tinctorum* plants collected in the flowering season. The total nitrogen, phosphorus, potassium, calcium, sodium, manganese, zinc and copper values lie within the ranges:

Table 5. Regression analysis of soil organic matter and plant mangenase content in *C. tinctoria.*

Linear Fit					
Summary of Fit					
Rsquare	0.245518				
Root Mean Square Error	16.966675				
Mean of Response	65.95238				
Observations (or Sum Wgts)	42				
Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Ratio	
Model	1	3747.074	3747.07	13.0165	
Error	40	11514.831	287.87	Prob>F	
C Total	41	15261.905		0.0008	
Parameter Estimates					
Term		Estimate	Std Error	t Ratio	Prob>|t|
Intercept		81.09974	4.94784	16.39	0.0000
Soil Organic Matter %		-6.26232	1.73575	-3.61	0.0008
Bivariate					
Variable		Mean	Std Dev	Correlation	Signif. Prob	Number
Soil Organic Matter %		2.41881	1.526578	-0.4955	0.0008	42
Plant Manganase %		65.95238	19.29356			

Table 6. Regression analysis of soil pH and plant potassium content in *R. tinctorum.*

Linear Fit					
Summary of Fit					
Rsquare	0.344763				
Root Mean Square Error	0.382357				
Mean of Response	2.609756				
Observations (or Sum Wgts)	41				
Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Ratio	
Model	1	3.0000257	3.00003	20.5205	
Error	39	5.7016719	0.14620	Prob>F	
C Total	40	8.7016976		0.0001	
Parameter Estimates					
Term		Estimate	Std Error	t Ratio	Prob>|t|
Intercept		-3.665046	1.38647	-2.64	0.0118
Soil pH		0.8432215	0.18614	4.53	0.0001
Bivariate					
Variable		Mean	Std Dev	Correlation	Signif. Prob	Number
Soil Organic Matter %		7.441463	0.324781	0.587165	0.0001	41
Plant Potassium %		2.609756	0.466414			

1.078%-2.898%, 0.032-0.282%, 1.78-3.36%, 1.18-2.80%, 0.06-0.36%, 50-200, 34.3-102.9 and 8-20 respectively in terms of dry weight. It is a well-known fact that nitrogen content in plants generally varies between 0.2 and 6 percent (29). Considering these upper and lower values, we can say that both plants contain

Table 7. Regression analysis of soil potassium and plant calcium content in *R. tinctorum.*

Linear Fit					
Summary of Fit					
Rsquare	0.18678				
Root Mean Square Error	0.469776				
Mean of Response	2.020244				
Observations (or Sum Wgts)	41				
Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Ratio	
Model	1	1.976819	1.97682	8.9575	
Error	39	8.606879	0.22069	Prob>F	
C Total	40	10.583698		0.0048	
Parameter Estimates					
Term		Estimate	Std Error	t Ratio	Prob>|t|
Intercept		1.5744156	0.16695	9.41	0.0000
Soil Organic Matter %		8.8470958	2.95602	2.99	0.0048
Bivariate					
Variable		Mean	Std Dev	Correlation	Signif. Prob	Number
Soil Potassium %		0.050732	0.025128	0.43218	0.0048	41
Plant Calcium %		2.020244	0.514385			

Table 8. Regression analysis of soil organic matter and plant sodium content in *R. tinctorum.*

Linear Fit					
Summary of Fit					
Rsquare	0.210265				
Root Mean Square Error	0.094327				
Mean of Response	0.174146				
Observations (or Sum Wgts)	41				
Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Ratio	
Model	1	0.09238945	0.092389	10.3837	
Error	39	0.34700567	0.008898	Prob>F	
C Total	40	0.43939512		0.0026	
Parameter Estimates					
Term		Estimate	Std Error	t Ratio	Prob>|t|
Intercept		0.2453516	0.02656	9.24	0.0000
Soil Organic Matter %		-0.023834	0.0074	-3.22	0.0026
Bivariate					
Variable		Mean	Std Dev	Correlation	Signif. Prob	Number
Soil Organic Matter %		2.987561	2.016442	-0.45855	0.0026	41
Plant Potassium %		0.174146	0.104809			

nitrogen within the accepted limits. The dry-weight phosphorus content of plants optimally lies between 0.05 and 0.43% (29). Both the plants investigated here have phosphorus contents within the given range. Both plants have the normal limits for potassium, which are optimally 11% and 0.2% (29). It has been reported that plants

should contain at least 0.93 percent calcium and that the optimum range is 4-7 percent (3). Considering this range, both *C. tinctoria* and *R. tinctorum* display normal calcium contents. Plants normally contain 0.01 to 10 percent total sodium, 10-694 manganese, 2-240 zinc and 1-500 cooper (21). The values obtained in the present study lie within these ranges. Sodium, manganese, zinc and potassium were observed to be higher in *R. tinctorum*, whereas nitrogen, phosphorus and calcium were higher in *C. tinctoria.* The values for copper were the same in both species.

Statistical Evaluation of the Soil and Plant Analysis Results

An attempt was made to determine relationships between the organic matter, P, K, pH, total soluble salts, $CaCO_3$ content of the soils and the N, P, K, Ca, Na, Mn, Zn and Cu content of the *C. tinctoria* and *R. tinctorum* plants. From the regression analyses four relevant correlations were obtained, two of these negative and the other two positive. The latter were observed between pH and K; and K and Ca, and the former between organic matter and Mn, and Na and organic matter. No other relevant correlations were obtained. Regression curves and correlation coefficients showed that a negative correlation exists between soil organic matter and plant manganese content in *C. tinctoria* (r: 0.48, Table 5, Fi: 1). In *R. tinctorum* positive correlations between soil pH and plant potassium (r: 0.58, Table 6, Fig: 2), and soil potassium and plant calcium (r: 0.42, Table 7, Fig. 3) were obtained. However, a negative correlation between soil organic matter and plant sodium (r: 0.45, Table 8, Fig. 4) was obtained. Other results gave neither positive nor negative correlations. Since the probability values of the four correlations were less than 0.05, the correlation coefficients and models were significant. In *R. tinctorum*, a reliable correlation exists between soil pH and plant potassium and the other three correlations are important according to Smith et al. (30). In terms of Per r^2 values, the soils of these plants appear to be poor in nutrients.

Autecological studies on the plant species which grow in Turkey and are used for dyes are quite limited. Consequently, autecological studies were performed on *C. tinctoria* and *R. tinctorum,* which are used as a source of dye for carpets, kilims and textiles in western Anatolia. These plants have also been used in medicine, which augments the importance of this research. We except that these autecological findings will help the cultivation of *C. tinctoria* and *R. tinctorum* in the future and this will prove to be an asset to the economy of Turkey.

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