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Morphological Variation and Plant Nutrients Effects of Two Taxonomically Distant *Centaurea* L. Species

SEZGIN ÇELIK*, KÜRSAD ÖZKAN† and ERSIN YÜCEL‡
Department of Technical Programs, School of Vocational
Kirikkale University, Kirikkale, Turkey
E-mail: sezgincelik@kku.edu.tr; sezgin_celik@yahoo.com

In this study, the influence of habitat on *Centaurea mucronifera* and *C. pyrrohoplephara*, whose morphological variants show obvious differences, spreading on calcareous soils of Mediterranean, Central and East Anatolia were examined. *C. mucronifera* and *C. pyrrohoplephara* are both perennials and have the height between 4 and 50 cm. The influence of nutrition elements in plant and physical and chemical properties of soils on morphological variations of *C. mucronifera* and *C. pyrrohoplephara* were determined with the models that have the highest explanation portion without multiple linkage problems on the base of model and variant and their relationships were investigated by using Stepwise Regression Analysis. It was found that there was a univariate independent model, showing the positive contribution of phosphorus content of root on plant nutrition element content and root length and for sodium content of stem on length of basal leaf and outer whorl of pappus in *C. mucronifera*. In *C. pyrrohoplephara*, between morphological characteristics and plant nutrition elements, on the base of model and variant, models having highest explanation portion without multiple relation problems were defined for variants of root length, plant length, width of basal leaf, capitula and involucrum, achene length, pappus inner whorl length. There was not any defined model determining the relationships between physical and chemical properties of soils and length and width of terminal leaf ($p < 0.05$). According to these results, it was found that, for *C. mucronifera* and *C. pyrrohoplephera*, physical and chemical properties of soils have an important role on the morphological structure of these species and there could be relationships between morphological structures of these taxa and the ratios of the variants of these plant nutrition element contents and also the influence of plant nutrition elements on the morphological differentiations of these species is relatively low ($p < 0.05$)

Key Words: *Centaurea* L., Morphology, Soil and Nutrients effects.

INTRODUCTION

Soil is one of the most important factors on spread of plants and variations of the plant morphology[1-4]. The individuals which belong to the same plant

†Department of Soil Science and Ecology, Suleyman Demirel University, Isparta, Turkey.
‡Department of Biology, Faculty of Science, Anadolu University, Eskisehir 26450, Turkey.

species sometimes show morphological variation at different ecological environments and the result of that ecotypical differences occur[5-7]. The differentiation of soil is more effective on ecotypical differences. It also has an important role for occurrence of genetical variations[7,8]. The species concept which depends on type is used for the determination and distinction of systematic categories while Flora of Turkey was written[9]. While the species were separated from each other the morphology of plants were generally explained, but they haven't determined the morphological features of plants which spread at the different locations. The new systematic groups occur with the change of morphological character's measure which especially used to separate species and subspecies character in the wide genera. The soil environment of natural ecosystems is heterogeneous both in time and space, even on a small scale[10]. Plant response to nutrient values can include changes in biomass allocation, in uptake kinetics or in root morphology[10-12]. Some of the competitive, dominant species do not respond to nutrient values by the changes listed above, but their roots represent a large part of root biomass in values because of their high growth rate[13]. Grime[13] suggested that subordinate species forage by their roots more precisely than dominant species and that the dicotyledonous species forage more precisely than the grasses. According to Grime[13] a trade-off exists between the scale (high for dominant plants) and the precision (high for sub-dominant plants) in resource foraging. Einsmann *et al.*[11] did not confirm Grime's[13] prediction. They found that scale and precision positively correlated in herbaceous species.

Turkey has an extremely rich flora due to its geographical location, ecological properties, paleogeography and vegetation history. Although, Turkey has one fifteenth of total land covered by European countries, it has an overwhelming number of endemic species. The records show that the European countries other than Turkey possess 12000 species of which 2750 are endemic. In Turkey, the number of species was estimated as 9000 of which 30 % are endemic. The genus *Centaurea* is the third largest genus after *Astragalus* and *Verbascum* in Turkey and represented by 187 taxa, of which 114 are endemic (endemism ratio: % 60.7)[9,14,15]. High endemism ratio shows that Turkey is one of the gene centres of the genus.

The multidirectional environmental interactions and relations in natural populations of *C. mucronifera* and *C. pyrrohoblephera*, *i.e.*, the effects of the plant nutrition elements and physical and chemical properties of soil, were examined. The systematic situation of species of this section, morphological descriptions which could not be explained obviously in the flora, the relationships between plant and soil in natural areas and the ecology of these areas were especially examined.

EXPERIMENTAL

Plant specimens belonging to *C. mucronifera* and *C. phyrrohoblephara* species were collected from three known localities in Irano-Turanian and Mediterranean regions in Turkey. The plant specimens were identified according to Wagenitz[9] and they are kept in the Herbarium of Biology Department (Çanakkale Onsekiz Mart University). Soil specimens (0-10, 10-20 and 20-30 cm deep) were collected from the area where the plant specimens were obtained and brought into the laboratory for analysis. The analyses were carried out according to Walkley and Black[16], Jackson[17], Chapmann and Pratt[18], Bouyoucus[19] and Olsen and Sommers[20]. The plant analyses were predicated on the root, stem and leaves. It was aimed to determine that whether the plant nutrition element content of each organ has different influences or not.

Stepwise regression analysis was used as statistical method. The models don't have any multiply relation problem. Because, VIF values of the models are less then 5, F values and t values of models are suitable with each other. All of the independent variables in the models are significant level at 5 %. Besides, the outputs of simple correlation analysis between the independent variables of the models have same directions[21].

C. mucronifera is perennial with robust woody rootstock, forming tufts with numerous sterile shoots. *C. pyrrohoblephara* is a perennial species with sterile shoots and several stems with 1-2 capitula. *C. mucronifera* was collected from 16 different localities from Central, Mediterranean and East Anatolian regions. *C. pyrrohoblephara* specimens were collected from 14 localities at Central and East Anatolian regions (Fig. 1). At least 20 plant specimens were collected from each locality and morphological measurements were done with digital calliper and the mean values of these measure-ments were taken into account. The morphological observations and biometric measurements were made on both fresh and herbarium specimens. In conservational biology studies, the relationships between *C. mucronifera* and *C. phyrrohoblephara* and the other species were evaluated.

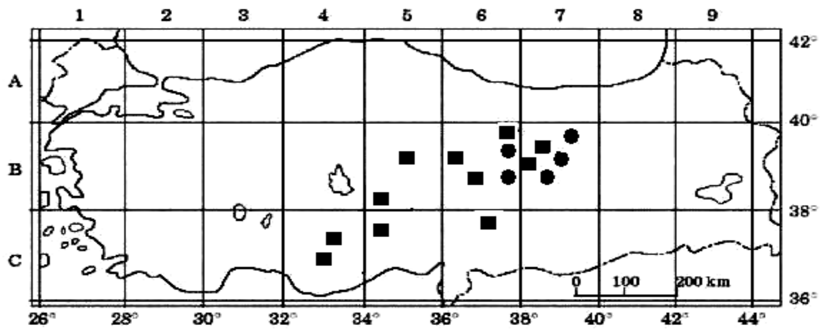

Fig. 1. Distribution of *C. mucronifera* (■ n = 16 areas) and *C. pyrrohoblephara* (• n = 14 areas)

Morphometry: A set of morphological traits was measured for all the plants *i.e.*, root length (maximum root length (cm)), plant height (from the soil surface to the apex of the plant (cm)), length of basal leaves (sampling with the medial part, cm), width of basal leaves, length of terminal leaf, width of terminal leaf, width of capitulum, length of capitulum, width of involucre, length of involucre, width of achene, length of achene, length of inner whorl of pappus, length of outer whorl of pappus (the species in this section has double lined pappus and this is an important character for identification for this reason it was measured (Table-1).

TABLE-1
MORPHOLOGICAL VARIABLES OF *C. mucronifera* and *C. pyrohoblephara* (Mean ± SE)

Morphological variable	*C. mucronifera* (Mean ± SE)	*C. pyrohoblephara* (Mean ± SE)
Root length	17.9 ± 1.37	102.7 ± 6.91
Plant height	261.0 ± 141.5	371.0 ± 13.40
Length of basal leaves	62.6 ± 9.47	73.7 ± 3.33
Width of basal leaves	5.72 ± 0.35	12.3 ± 0.83
Length of terminal leaf	59.2 ± 5.54	75.5 ± 3.34
Width of terminal leaf	5.12 ± 0.38	16.3 ± 1.14
Width of capitulum	18.8 ± 2.56	36.4 ± 1.95
Length of capitulum	20.9 ± 3.53	34.9 ± 2.16
Width of involucre	18.8 ± 1.89	21.5 ± 1.23
Length of involucre	21.3 ± 2.96	23.4 ± 1.29
Width of achen	2.57 ± 0.49	1.60 ± 0.15
Length of achen	6.57 ± 0.38	6.51 ± 0.41
Length of inner whorl of pappus	2.79 ± 0.35	2.40 ± 0.23
Length of outer whorl of pappus	5.76 ± 0.37	6.15 ± 0.25

RESULTS AND DISCUSSION

Morphological variation of plants and plants nutrients effects: There was no available model related with the root length, plant length, width of basal leaf, width and length of terminal leaf, width and length of capitula, width and length of involucrum, width and length of achene, pappus inner whorl length and the nutrition element content of root, stem and leaf of *C. mucronifera* ($p < 0.05$). On the contrary the other morphological variants were explained with uni-independent variant at the significance level of 5 %. These were the models showing the positive contribution of P content of root on increase in root length, sodium content of stem on basal leaf area and thickness of outer whorl of pappus. For the variants of basal leaf width, terminal leaf length and width, capitula length, involucrum length, achene width and length of inner whorl of pappus at the level of 5 % significance, there was no available model related with the root, stem and leaf nutrition contents of *C. pyrrohoblephera*. For root length and thickness, plant length, widths of basal leaf, capitulum and involucrum, achene length and inner whorl length of pappus, there were some defined models, on the base of both model and variant, having the highest explanation portion without multiple relation problems at the level of 5 % significance. These models were as follows; positive influence of Mn^{2+} content of stem and Cu^{2+} content of root and negative influence of N % of stem on increase in root length; negative influence of N % on increase in root thickness; positive influence of P^{+} content of root on increase in plant length; negative influence of N % content of leaf and positive influence of Cu^{2+} content of root on basal leaf width; negative influence of N % content of root on the increase in capitulum width; positive influence of Zn^{2+} contents of both root and leaf and negative influence of Cu^{2+} content of leaf on increase in involucrum width; positive influence of N % in root on increase in achene length and negative influence of Mn^{2+} content of stem on increase in length of pappus outer whorl (Table-2).

Morphological varition of plants and soil nutrients effects: The models having highest explanation portion without multiple relation problems on the base of both model and variant at the level of 5 % significance were defined for morphological variants of *C. mucronifera* (Table-3) and *C. pyrrohoblephara* (Table-4).

The contributions of the variants to *C. mucronifera* according to these defined models were as follows; K^{+} (0-10 cm), clay % (0-10 cm) had positive and Fe^{2+} (20-30 cm) had negative contribution on changes of plant length. The contributions of pH (0-10 cm) and Fe^{2+} (10-20 cm) on root length were negative, while the contributions of Fe^{2+} (10-20 cm) and Mn^{2+} (0-10 cm) on root thickness were negative and that of Cu^{2+} (10-20 cm) was positive. For basal leaf length the contributions of Cu^{2+} (10-20 cm) was positive. The contribution of K^{+} (10-20 cm) on changes in basal leaf width, terminal leaf width and capitula length was positive. The contributions of sand (0-10 cm) and Fe^{2+} (20-30 cm) on changes in capitula width was negative, while the contributions of clay (0-10 cm), Mn^{2+} (20-30 cm), pH (10-20 cm) on the changes in involucrum width were positive. The contribution of Fe^{2+} (20-30 cm) was negative and the contribution of Cu^{2+} (10-20 cm) on involucrum length were positive, while the contributions of sand (10-20 cm), clay (0-10 cm) and salt (0-10 cm) on changes in achene length were positive that of Fe^{2+} (20-30 cm) was negative. The contributions of clay (0-10 cm) and Ca^{2+} (10-20 cm) on changes in achene length were positive but that of organic matter (0-10 cm) was negative. The contributions of pH (0-10 cm) and dust (20-30 cm) on changes in pappus inner whorl length and the

TABLE-2
THE BEST STEPWISE REGRESSION ANALYSIS MODELS OF MORPHOLOGICAL CHARACTERS OF *C. mucronifera* AND *C. pyrrhoblephera* ACCORDING TO ROOT, STEM AND LEAF NUTRIENT VARIABLES

Morphological variables	R^2	F	Sig.	*C. mucronifera* Model coefficients	R^2	F	Sig.	*Centaurea pyrrhoblephera* Model coefficients
1	0.364	8.009	0.013	Root length = 281.148 + 0.111 (P root)	0.856	19.815	0.000	Root length = 95.837 + 0.136 (Mn^{2+} stems) + 0.809 (Cu^{2+} root) – 0.0932 (Na^+ stems)
2	-	-	-	Plant height	0.557	15.063	0.002	Plant height=347.804 + 0.03653 (P root)
3	-	-	-	Length of basal leaves	0.594	8.058	0.007	Length of basal leaves = 75.126 – 0.0419 (Na^+ leaf) + 0.490 (Cu^{2+} root)
4	0.254	4.770	0.046	Width of basal leaves = 5.037 + 0.005477 (Na steam)	-	-	-	Width of basal leaves
5	-	-	-	Length of terminal leaf	-	-	-	Length of terminal leaf
6	-	-	-	Width of terminal leaf	-	-	-	Width of terminal leaf
7	-	-	-	Width of capitulum	0.300	5.142	0.043	Width of capitulum = 39.391 – 0.0253 (Na^+ root)
8	-	-	-	Length of capitulum	-	-	-	Length of capitulum
9	-	-	-	Width of involucre	0.747	9.833	0.003	Width of involucre = 19.679 – 0.263 (Cu^{2+} leaf) + 0.08198 (Zn^{2+} root) + 0.08218 (Zn^{2+} leaf)
10	-	-	-	Length of involucre	-	-	-	Length of involucre
11	-	-	-	Width of achen	-	-	-	Width of achen
12	-	-	-	Length of achen	0.384	7.479	0.018	Length of achen = 6.245 + 0.169 (N % root)
13	-	-	-	Length of inner whorl of pappus	-	-	-	Length of inner whorl of pappus
14	0.277	5.359	0.036	Length of outer whorl of pappus = 5.020 + 0.005948 (Na^+ steam)	0.554	14.898	0.002	Length of outer whorl of pappus = 6.408 – 0.00462 (Mn^{2+} steam)

TABLE-3
THE BEST STEPWISE REGRESSION ANALYSIS MODELS OF MORPHOLOGICAL CHARACTERS OF *C. mucronifera* ACCORDING TO SOIL (0-10, 10-20, 20-30 cm) VARIABLES

Morphological variables	R^2	F	Sig.	Model coefficients
1	0.489	6.233	0.013	Root length = 1129.360 - 84.325 (Fe^{2+}_{10-20})-106.324 (pH_{0-10})
2	0.809	16.892	0.000	Plant height = 297.215+7.141(Clay $\%_{0-10}$) - 252.467(Fe^{2+}_{20-30}) + 0.526 (K^{+}_{0-10})
3	0.338	7.145	0.018	Length of basal leaves = 40.438 + 35.798 (Cu^{2+}_{10-20})
4	0.476	12.693	0.003	Width of basal leaves = 5.405 + 0.001678 (K^{+}_{10-20})
5	-	-	-	Length of terminal leaf
6	0.272	5.223	0.038	Width of terminal leaf = 4.855 + 0.001392 (K^{+}_{10-20})
7	0.589	9.310	0.003	Width of capitulum = 28.891 – 0.08918 (Sand $\%_{0-10}$) – 4.729 (Fe^{2+}_{20-30})
8	0.349	7.515	0.016	Length of capitulum = 18.240 + 0.01441 (K^{+}_{10-20})
9	0.809	11.667	0.001	Width of involucre = -2.741 + 0.158 (Clay $\%_{0-10}$) – 3.565 (Fe^{2+}_{20-30}) + 5.464 (Mn^{2+}_{20-30}) + 2.745 (pH 1_{0-20})
10	0.400	9.349	0.009	Length of involucre = 13.755 + 12.164 (Cu^{+4} 10-20)
11	0.829	13.303	0.000	Width of achen = 0.154 + 0.07643 (Clay $\%_{0-10}$) - 0.945 (Fe^{2+}_{20-30}) + 3.988 ($NaCl_{0-10}$) + 0.01801 (Sand % 10-20)
12	0.776	13.823	0.000	Length of achen = 6.223 + 0.02811 (Clay $\%_{0-10}$) + 0.00007 (Ca^{+}_{10-20}) – 0.04509 (Org. Mat $\%_{0-10}$)
13	0.544	7.763	0.006	Length of inner whorl of pappus = -5.565 + 1.049 (pH 0-10) + 0.01677 (Dust $\%_{20-30}$)
14	0.533	8.032	0.005	Length of outer whorl of pappus = -1.524 + 0.928 (pH_{0-10}) + 0.02043 (Clay $\%_{0-10}$)

TABLE-4
THE BEST STEPWISE REGRESSION ANALYSIS MODELS OF MORPHOLOGICAL CHARACTERS OF *C. pyrrohoblephera* ACCORDING TO SOIL VARIABLES

Morphological variables	R^2	F	Sig.	Model coefficients
1	0.625	9.148	0.005	Root length = 110.629-0.0182(Mg^{+}_{0-10})-20.817($N\%_{0-10}$)
2	0.981	58.677	0.000	Plant height = 362.871-0.240 (P_{20-30}) + 137.003(Mn^{2+}_{20-30}) -91.397 (Mn^{2+}_{10-20}) + 47.010(Cu^{2+}_{0-10}) - 0.04580($Clay_{0-10}$) -37.955(Cu^{2+}_{20-30})
3	0.846	18.377	0.000	Length of basal leaves = 71.190 + 0.01937(K^{+}_{20-30})-9.625($N\%_{0-10}$) + 0.105($Lime_{20-30}$)
4	0.420	8.682	0.012	Width of basal leaves = 12.936 – 3.206 ($N\%_{0-10}$)
5	-	-	-	Length of terminal leaf
6	-	-	-	Width of terminal leaf
7	0.706	13.230	0.001	Width of capitulum = 36.781-0.378($Org.Matter\%_{0-10}$) + 0.02083(P_{0-10})
8	0.999	1099.42	0.000	Length of capitulum = 34.116-5.438 ($N\%_{20-30}$) -0.005189 (Mg^{+}_{10-20}) + 0.008201(Mg^{+}_{20-30}) + 0.01634(P_{20-30})-0.220 ($Org. Matter\%_{10-20}$) + 0.001015 (Ca^{+}_{0-10}) + 0.368(Fe^{2+}_{10-20}) + 0.370(Fe^{2+}_{0-10})
9	0.880	24.335	0.000	Width of involucre = 17.632 + 2.619(Fe^{2+}_{10-20}) + 4.230(Mn^{2+}_{10-20})-2.940 ($N\%_{20-30}$)
10	0.705	13.150	0.001	Length of involucre = 19.503 + 2.408 (Fe^{2+}_{10-20}) + 3.755(Mn^{2+}_{10-20})
11	0.954	47.114	0.000	Width of achen = 2.373-0.003023 (P (20-30)-0.006868 (Sand(0-10) - 0.03939(Na^{+}(0-10)) + 0.378 NaCl (20-30)
12	0.658	10.563	0.003	Length of achen = 7.387-1.083 (Zn^{2+}_{0-10})-0.423 (Fe^{2+}_{10-20})
13	0.461	10.263	0.008	Length of inner whorl of pappus = -0.949 + 0.429 (pH_{20-30})
14	0.627	9.258	0.004	Length of outer whorl of pappus = 5.457 + 1.123(Mn^{2+}_{10-20}) + 0.001767(Mg^{2+}_{10-20})

contributions of pH (0-10 cm), clay % (0-10 cm) on changes in pappus outer whorl length were positive. The only morphological characteristics that did not have any correlation with soil properties were the terminal leaf length.

The contributions of the variants to *C. pyrrohoblephara* according to the defined models were as follows: the contributions of Mg^{2+} (0-10 cm) and N % (0-10 cm) on changes in root length were negative, while the contributions of Cu^{2+} (0-10 cm), P (20-30 cm) on changes in root thickness were negative, that of $CaCO_3$ % (20-30 cm) and Mn^{2+} (10-20 cm) were positive; the contributions of Mn^{2+} (20-30 cm), Cu^{2+} (0-10 cm) on the changes in plant length were positive on the contrary that of Mn^{2+} (10-20 cm), P (20-30 cm), clay (0-10 cm) and Cu^{2+} (20-30 cm) were negative. The contributions of K^+ (20-30 cm), $CaCO_3$ % (20-30 cm) were positive but that of N % (0-10 cm) was negative on basal leaf width. The contribution of N % (0-10 cm) on the changes in basal leaf width was negative, while the contributions of P (0-10 cm) on changes in capitula width was positive and that of organic matter (0-10 cm) was negative. The contributions of Mg^{2+} (20-30 cm), P (20-30 cm), Ca^{2+} (0-10 cm), Fe^{2+} (0-10 cm) and Fe^{2+} (10-20 cm) were positive on the contrary that of N % (20-30 cm), Mg^{2+} (10-20 cm), organic matter % (10-20 cm) were negative on the changes in capitula length. The contributions of Fe^{2+} (10-20 cm) and Mn^{2+} (10-20 cm) on changes in involucrum width were positive on the contrary that of N % (20-30 cm) was negative. The contributions of Fe^{2+} (10-20 cm) and Mn^{2+} (10-20 cm) on changes in involucrum length were positive, while the contribution of NaCl (20-30 cm) on the changes in achene width was positive that of P (20-30 cm), sand % (0-10 cm) and Na^+ (0-10 cm) were negative. The contributions of Zn^{2+} (0-10 cm) and Fe^{2+} (10-20 cm) on the changes in achene length were negative. The contribution of pH (20-30 cm) on the changes in inner whorl pappus length was positive. The contributions of Mn^{2+} (10-20 cm) and Mg^{2+} (10-20 cm) on the length of pappus outer whorl were positive. There was not any relationship detected between soil properties and the terminal leaf length and width of *C. pyrrohoblephara*.

Studies on plant drag in relation to morphology would lead to a better understanding of the relationship between morphological patterns and function[22]. Drag measurements could link morphological changes to the forces really encountered by plants and thereby measure the real benefit of morphological change. The very high morphological variability of *C. mucronifera* and *C. pyrrohoblephara* along the gradient raises the issue of the capacity of the species to colonise such habitats, characterized by a high stress level. The morphological variability observed probably reflects the plasticity of the species. Indeed the rare examples of genotypic differentiation between populations encountering contrasting flow stress concern distant (several km) algal species[23,24].

It was found that the content of phosphorus in the plant root positively influence the root length of *C. mucronifera*. There may be less availability of phosphorus in a rapidly drying soil due to reduced phosphorus diffusion and poor uptake by roots[25]. This may result in inadequate phosphorus nutrition for cotton plants. Consequently, phosphorus deprivation is expected to have a large and rapid negative effect on the rate of leaf expansion and final growth, irrespective of any influence phosphorus may have on the plant water relations, as has been reported for various crops[26]. Soil drying may induce a decrease in nutrients, in addition to a restriction in available water, with strong interactive effects on plant growth and function[27,28]. Leaf area in plants with adequate nutrition is strongly linked to plant growth and yield[29].

The relationships between the basic morphological characteristics and the nutritional material contents of root, stem and leaves in both of the species were very few. This probably means that for the morphological development of *C. mucronifera* and *C. pyrrohoblephara*, rather than the nutrient content of root, stem and leaves, the ratios of these nutritional variants were effective and for the ecotypical differentiations in these species it was found that the plant chemical characteristics were less in importance. These results show that for the morphological development of *C. mucronifera* and *C. pyrrohoblephara* soil properties have important role. Also for *C. pyrrohoblephara* there was not any relationship between terminal leaf length and width and soil properties means that these characteristics could be the key morphological characteristics of this species in the separation of genotypes. Besides, for the species of the separate areas, differences of the systematically important morphological characteristics and the observed ecotypical differentiations were fundamentally influenced by the physical and chemical nutritional elements of both plant and soil.

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