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Canonical Correlation Analysis for Studying the Relationship Between the Basic Morphological and Some Soil Chemical Characteristics of *Centaurea mucronifera* DC. (*Asteraceae*)

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This aim of this study was to investigate the relationship between the basic morphological features and some soil chemical characteristics in order to enlighten the differentiation in the *Centaurea mucronifera* populations distributed at 16 different places under varying environmental conditions. For this purpose method of Canonical correlation analysis (CCA) was used. The results revealed that morphological features like length of terminal leaves (Y3), length of capitula (Y4), length of involucrum (Y5) and length of achen (Y6) are affected positively by N (X6) and Ca^{2+} (X7) in the soil but the length of plant (Y1), length of basal leaves (Y2) and length of pappus (Y7) are affected negatively.

Key Words: *Centaure mucronifera*, Morphology, Soil chemistry, Canonical correlation analysis.

INTRODUCTION

Soil is one of the major factors playing an important role in the distribution of plants and variations in their morphological features[1,2]. Even the plants of the same species sometimes show morphological variations under different ecological conditions resulting in the formation of ecads[3,4]. A similar situation is met within the genus *Centaurea* L., where difficulties are faced during the taxonomical identifications. This genus is the third largest genus in Turkey, represented by 187 taxa, of which 115 are endemics, with a ratio of endemism lying around 61.5 per cent[5-7]. This high endemism ratio shows that Turkey is one of the gene centers of this genus. The aim of this study was to investigate the relationship between the basic morphological features and some soil chemical characteristics of *C. mucronifera* in order to enlighten the population differentiations observed in this species.

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EXPERIMENTAL

The specimens of *C. mucronifera* DC. were collected from (Kayseri, (N 38º.08' E 35º.26', N 39º.13'E 36º.26', N 39º.08'E 36º.20', N 38º.38' E 36º.29'),Yozgat (N 39º.25' E 35º.36', N 39º.18'E 35º.29'), Kahramanmaras (N 38º.03' E 36º.32', N 38º.03'E 36º.31'), Sivas (N 39º.25 E 38º.03', N 38º.42' E 37º.16'), Erzincan (N 39º.15' E 38º.31', N 39º.16'E 38º.32'), Konya (N 36º.37' E 38º.32'), Karaman (N 37º.13' E 32º.56', N 37º.15' E 32º.54') and Nigde (N 37º.32' E 34º.27') (Fig. 1). These were identified with the help of Flora of Turkey and East Aegean Islands[5] and deposited at the Herbarium of Canakkale Onsekiz Mart University (Collecter No: Celik 2050-2100), Canakkale, Turkey.

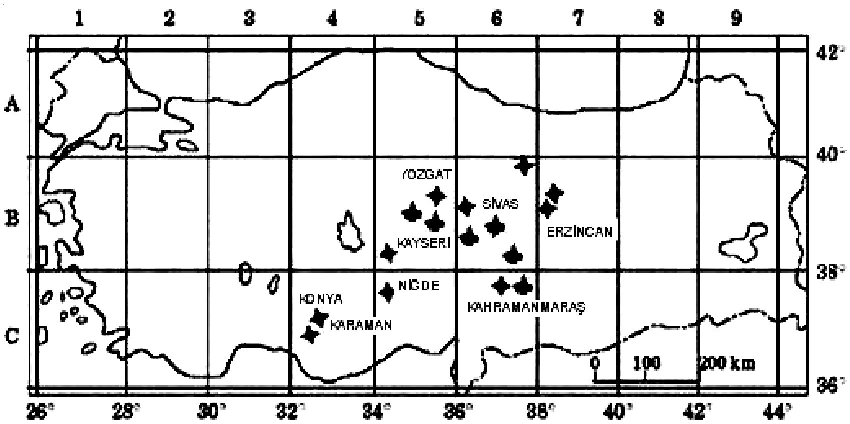

Fig. 1. Distribution of *Centaurea mucronifera* in Turkey

The morphological features such as, length of plant, length of basal leaves, length of terminal leaves, length of involucrum, length of achene and length of pappus were recorded. The interrelations of *C. mucronifera* with its associates too were evaluated. The soil samples from a depth of 0-30 cm from the localities of collected specimens were taken and brought to the laboratory for analysis. These were air dried and pH, organic matter, EC (mmhos), P_2O_5 (%), N(%) and Ca^{2+} (ppm) determined according to the methods of Walkley and Black[8], Jackson[9], Chapmann and Pratt[10] and Olsen and Sommers[11].

Statistical analysis: Canonical correlation analysis (CCA) was used to investigate the relationships between the soil chemical characteristics and morphological features. This analysis was performed with Sas Proc Cancorr[12]. From CCA, a linear association between predictor variables (soil chemical characteristics) and dependent variables (morphological features) were determined. Canonical variables are linear combinations of the original quantitative measurements that contain the highest possible multiple correlations with each group and that summarize among-class variation. The goal of CCA is to evaluate the relative contribution of each variable to the derived canonical functions in order to explain nature of the relationship(s). Consider the following two equations:

$$U_m = a_{m1}X_1 + a_{m2}X_2 + ... + a_{mp}X_p \quad (1)$$

$$V_m = b_{m1}Y_1 + b_{m2}Y_2 + ... + b_{mp}Y_p \quad (2)$$

Eqns. 1 and 2 gives the new variables U_m and V_m which are a linear combination of the X (soil chemical characteristics) and Y (morphological features) variables respectively. Eqns. 1 and 2 are the canonical equations, U_m and V_m are the canonical variates and C_m (the correlation between U_m and V_m can be called canonical correlation) is the canonical correlation[12,13]. Squared canonical correlation represents the amount of variance in one canonical variate accounted for by the other canonical variate[14].

The null (H_0) and alternative (H_1) hypotheses for assessing the statistical significance of the canonical correlations (C_m) are:

$$H_0 : C_1 = C_2 = ... C_m = 0$$

H_1 : at least one of the canonical correlations is different from zero.

The Wilks' Lambda can be used for testing this hypothesis.

The standardized coefficients are similar to the standardized regression coefficients in multiple regressions that can be used as an indication of relative importance of the predictor or independent variables in determining the value of the dependent variable. Therefore, the objective of canonical correlation is to estimate a_{m1}, a_{m2} ... a_{mp} and b_{m1}, b_{m2} ... b_{mp} such that C_m is maximum. On the other hand, large canonical correlation does not always mean that there is a powerful relationship between the two variable sets, because canonical correlation maximizes the correlation between linear combinations of variables in two sets of variables but does not maximize the amount of variances accounted for in one set of variables by the other set.

Therefore, it is suggested to calculate the redundancy measure (RM) for each canonical correlation to determine how much of the variance in one set of variables is accounted for by the other set of variables[14,15]. Redundancy measures (RM) can be computed for each canonical correlation. Let $RM_{(Ui/Vi)}$ the amount of variance in the Y variables that is accounted for by the X variables for the ith canonical correlation (C_i). Therefore, RM can be formulated as below:

$$RM_{(Ui/Vi)} = AV(Y/V_i)C_i^2 \quad (3)$$

where $AV(Y/V_i)$ is the average variance in Y variables that is accounted for by the canonical variate V_i and it can be formulated as

$$AV(Y/V_i) = \frac{\sum_{j=1}^{q} LY_{ij}^2}{q} \quad (4)$$

LY_{ij}^2 is the loading of the jth Y variable on the ith canonical variate, C_i^2 represent the shared variance between V_i and U_i and q is the number of traits in canonical variates mentioned.

RESULTS AND DISCUSSION

C. mucronifera is a perennial, with robust woody rootstock, forming tufts with numerous strerile shoots. Flowering stems are 3-40 cm long. Leaves grey-to-white tomentose; basal leaves lanceolate, oblong, rhomboid or nearly circular, 5-15 mm broad, long-petioled, cauline leaves few, of similar form. Involucre 15-22 (-25) × 9-15 (-20) mm. Appendages large, convex, hyaline, nearly orbicular, scarcely decurrent, minutely toothed or ciliate. Flowers are rose-purple, flowering occurs during June-August and achenes are 5-7, pappus 2-5 mm. It occupies rock crevices and screes (lime stone).

The descriptive statistical data is given in Table-1 and the canonical correlations, its standard error, R^2, redundancy measure and canonical variates are given in Table-2.

TABLE-1
DESCRIPTIVE STATISTICS OF SOIL CHEMICAL AND MORPHOLOGICAL CHARACTERISTICS OF *Centaurea mucronifera* DC.

Variables	Mean	SE Mean
Length of plant (Y1)	261.20	53.38
Length of basal leaves (Y2)	62.60	3.57
Length of terminal leaves (Y3)	59.26	2.09
Length of capitula (Y4)	20.93	1.33
Length of involucrum (Y5)	21.28	1.12
Length of achen (Y6)	6.57	0.14
Length of pappus (Y7)	5.76	0.14
pH (1/2.5) (X1)	7.69	0.08
Total lime (%) (X2)	12.51	6.56
Organic matter (%) (X3)	4.66	0.91
P_2O_5 (%) (X4)	45.23	16.62
EC mmhos (10^3) (X5)	0.45	0.11
N (%) (X6)	0.23	0.05
Ca^{2+} (ppm) (X7)	4460.45	898.40

The value of first canonical correlation is 0.986 and the likelihood ratio test indicates that it is statistically significant at alpha levels of 0.01

TABLE-2
CANONICAL CORRELATION, STANDARD ERROR, DETERMINATION COEFFICIENT (R^2), REDUNDANCY Measure (RM), Significance Level (P-value) and Canonical variates

Canonical correlation	Standard error	R^2	P	RM
0.986	0.007	0.972	0.000**	0.682
Canonical variates				
U1 = -0.647X1-0.089X2-0.621X3-0.636X4-0.228 X5 +0.577X6+ 0.749X7				
V1 = -0.829 Y1-1.061 Y2 +0.932Y3 +0.406 Y4+1.145 Y5 +0.655Y6 - 0.219Y7				

**p < 0.01

(p < 0.00); other cannonical correlations were not reported because they were nonsignificant (p > 0.05). Hence, the correlations between the set of variables (between soil and morphological features) can be accounted for by the just first pair of canonical variates (U1 and V1). The redundancy measure (RM) of 0.6284 for the first canonical variate suggests that about 62.84 % of the variance in the Y variables is accounted by the X variables. This value is large and we conclude that the first canonical correlation has a high practical significance[15].

The standardized canonical coefficients of the first canonical variate for the soil chemical characteristics (X variable set) suggest that the variables, X7, X1, X3 and X4 are influential in forming the first canonical variate (U1). Similarly, based on canonical coefficients of morphological features (Y variable set) Y5, Y2, Y3 and Y1, are more influential in forming the first canonical variate (V1).

The effect of X variables on the Y variables is assessed by the sign of the standardized coefficients or loadings[13,15]. When the coefficients of U1 and V1 equations were evaluated, since the coefficients of X6, X7, Y3, Y4, Y5 and Y6 are positive, we conclude that the X6 and X7 variables have a positive impact on the Y3, Y4, Y5 and Y6 variables. The most determinative soil chemical character was X7 with a coefficient of 0.749 and followed by X1 (0.647), X4 (0.636) and X3 (0.621). It can be said that while the Y3, Y4, Y5 and Y6 morphological features of *C. mucronifera* were affected positively from X6 and X7 soil chemical characteristics, Y1, Y2 and Y7 were negatively affected. Therefore, high determinations in the soil characters of N (X6) and Ca^{2+} (X7) lead to an increase in the morphological characters of lengths of terminal leaves (Y3), capitula (Y4), involucrum (Y5) and achen (Y6) except for the lengths of plant (Y1), basal leaves (Y2) and pappus (Y7).

X1, X2, X3, X4 and X5 soil chemical characteristics have negative affect on Y1, Y2 and Y7. In other words, the increase of pH (1/2.5) (X1), total lime (%) (X2), organic matter (X3), P_2O_5 (%) (X4) and EC (10^3) (X5) result in a decrease in the length of plant (Y1), basal leaves (Y2) and pappus (Y7). The most effective soil chemical characteristics which cause decrease in the length of plant (Y1), basal leaves (Y2) and pappus (Y7) are pH (1/2.5) (X1), organic matter (X3) and P_2O_5 (%) (X4). The most determinative soil chemical characteristic was X1, X4 and X3 with a coefficient of 0.647, 0.636 and 0.621, respectively.

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