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Habitat analyses of spurge species from Europe using multivariate techniques

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Ordination analyses were used to examine the relationships between four European spurge species, twenty-one chemical and physical variable from soil layer A (top two inches) and soil layer B (greater than two inches in depth), the % cover of grasses and forbs, and eighteen field sites from Europe. Spurge species included *Euphorbia cyparissias* L., *E. lucida* Waldst. and Kit., *E. seguieriana* Neck, and *E. virgata* Waldst. and Kit. Chemical and physical variables analyzed from the soil included: pH, Ca, Mg, K, Na, Cu, Fe, Mn, Zn, NH_4-N, NO_3-N, soil matrix potential (SMP), Olsen P (P), $CaCO_3$, total Kjeldahl nitrogen (TKN), electrical conductivity (EC), % organic matter, % sand, % clay, and % silt. The field sites comprised of four xeric, six open mesic, four closed mesic (two with low levels of shading and two with high levels of shading), and four riparian sites were located in Italy, Switzerland, Germany, Austria, and Hungary.

Principal Components Analysis (PCA) was conducted first to examine the relationship between each of the eighteen field sites with chemical/physical variables in the two soil horizons an five habitat types. In summarizing the PCA results from soil layer A, Ca, Mg, K, Na, Fe, Mn, Zn, NH_4-N, NO_3-N, SMP, P, TKN, EC, % organic matter, % clay, and % silt increased as one progressed from dry to more moist habitat types, while Cu, pH. and % sand decreased. PCA Aces 1 and 2 for soil layer A were found to explain 36 and 12.5% of the environmental variation (i.e., variation due to chemical and physical variables measured from the soil, plus the weighting by habitat type; $P < 0.0001$ for both axes). Similarly, for soil layer B, Ca, Mg, K, Na, Fe, Mn, Zn, NH_4-N, NO_3-N, SMP, P, TKN, EC, % organic matter, % clay, and % silt increased as one progressed form dry to more moist habitat types, while $CaCO_3$, pH, and % sand decreased. PCA Axis 1 and 2 for soil layer B were found to explain 38.8 and 16.9% of the environmental variation ($P < 0.0001$ for both axes).

Detrended Correspondence Analysis (DCA) was used to examine the relationship between fifteen of the eighteen field sites (for which plant community data was taken and at least one of the four species was present), the percent cover of grasses and forbs, and the four spurge species. *Euphorbia virgata* was found to be associated with sites containing relatively high levels of grasses and forbs, with three of the five field sites (where this species was present) containing higher levels of forbs than grasses. In contrast, *E. se-*

guieriana was found to be associated with relatively low levels of grass and forb cover, with the two sites that contained this plant species showing higher levels of grasses than forbs. *Euphorbia lucida* was found to be associated with sites with relatively high levels of both grasses and forbs, with forbs dominating at two of the three sites in which this plant species was found. In contrast, *E. cyparissias* was found to be associated with low to high levels of grass and forb species, with grasses generally dominating the drier sites and forbs generally dominating the more moist sites. DCA Axes 1 and 2 were found to explain 27.2 and 21.8% of the variation in the separation of the four spurge species and the percent cover of grasses and forbs along the ordination axes.

Canonical Correspondence Analysis (CCA) was used to examine the relationship between the four spurge species, chemical and physical variables in the two soil layers, and fifteen of the eighteen field sites (in which at least one of the four spurge species was present). The more xeric sites, *E. cyparissias*, and *E. seguieriana* were associated with lower levels of moisture and higher levels of % sand, soil pH, and $CaCO^3$. In contrast, closed mesic and riparian field sites were generally associated with higher levels of moisture, SMP, and % clay for both soil layers A and B. CCA axes 1 and 2 in soil layer A were found to explain 36.9 and 28.6% of the variation, respectively, in the separation of the four spurge species, grasses, and forbs along the CCA axes ($P < 0.01$ and $P < 0.31$, respectively). CCA axes 1 and 2 in soil layer B were found to explain 35.7 and 25.5% of the variation, respectively, in the separation of the four spurge species, grasses, and forbs along the CCA axes (P , 0.04 and $P < 0.42$, respectively).-N, NO3-N, soil matrix potential (SMP), Olsen P (P), $CaCO^3$, total Kjeldahl nitrogen (TKN), electrical conductivity (EC), % organic matter, % sand, % clay, and % silt. The field sites comprised of four xeric, six open mesic, four closed mesic (two with low levels of shading and two with high levels of shading), and four riparian sites were located in Italy, Switzerland, Germany, Austria, and Hungary.

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