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# RELATIONSHIPS BETWEEN SOIL SALINITY AND VASCULAR PLANTS IN INLAND SALT MEADOW NEAR THE TOWN OF RADNEVO

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***Abstract***

*Inland salt meadows are exclusively rare in Bulgaria. One of the most representative localities of this habitat in the country are the Inland salt meadows near the town of Radnevo. The object of this study is the inland salt meadow located north of the town of Radnevo near the village of Daskal Atanasovo between coordinates 42°19.60 and 42° 19.185 N, 25°53. 890 and 25° 54.506 E.It was developedonGleycVertisols, surface water logging, slightly saline soil.*
*The aim of the study was to investigate the relationship between soil salinity and the vascular plants in the Inland salt meadows near the town of Radnevo.*
*The survey was conducted in 2011-2012. A total of 60 soil samples were taken from a depth of 0-20 cm. In each sample taking point the vascular plants existing there were also collected. Electrical conductivitiy (EC) and pH of soils were analyzed. The relationship between soil EC values and the recorded 57 vascular plants was studied. A different saltiness level has been registered on the territory of the inland salt meadow. Four species - Taeniatherum caput-medusae (L.) Nevski, Trifolium repens L., Elymus elongatus (Host.) Runemark, Cynodon dactylon L. have been found at locations with varying saltiness level from weak to medium, and six species - Carex divisa Huds, Hordeum hystrix Roth, Alopecurus geniculatus L., Bromus commutatu Guss. ex Steuds, Carex distans Host. and Trifolium resupinatum L. have been found both on saline and non-saline soils. The dominating species on the studied territory have also been specified.*

**Key words:** *EC, Inland salt meadows, soil salinity, vascular plants.*

## INTRODUCTION

The Inland salt meadows are exclusively rare in Bulgaria. The habitat is included in: Red Data Book of Bulgaria in category Endangered (Tzonev and Gussev, 2011); Annex № 1 of the Biological Diversity Act (2007) and some of the localities are within sites of European Ecological Network NATURA 2000 in Bulgaria. One of the most representative localities of this habitat in the country is the Inland salt meadows near the town of Radnevo. An object of this study is the Inland salt meadow located north of the town of Radnevo near the village of Daskal Atanasovo between coordinates 42°19.60 and 42°19.185 N, 25°53. 890 and 25° 54.506 E and it occupies an area of 6.83 ha. According to the phytogeographical zoning adopted in the country their area is within the Thracian Lowland, at the border with Tundzha hilly country. The relief is plain, micro-depressions and surface waterlogging are available as a result of the high level of underground water and the low soil permeability.

Climatically the region is part of the transitional continental subregion of the European continental region. The average annual air temperature calculated for a period of many years is 12.3°C. Winter is relatively mild. The average monthly temperature for January, the coldest month of the year, is 1°C. Summer is relatively hot, with average monthly temperature in July – the hottest month of the year – of 23.4°C. With prolonged anticyclonic episodes maximum air temperatures exceed 36°C. The annual amount of precipitation in the region is below the average for the country. Two precipitation maxima are typical: summer – in May and June and winter – in November and December. Droughts start as early as the second half of July and last for 90 – 100 days, almost till the end of October. All these climatic characteristics result in the establishment of an evaporation type of water regime.

Salinity of soils in the inland areas is a secondary process occurring on already set soils with increased level of underground water and their higher mineralization or with improper drainage and irrigation (Ganchev et al., 1971; Dimitrov, 1987; Raikov et al., 1989). The Inland salt meadows in the region of Radnevo municipality were developed on Gleyc Vertisols, surface water logging, slightly saline soil. They were formed in shallow underground water and meadow plantation on clayey silt. According to geobotanical data a considerable part of these territories in the past were occupied by oak and hornbeam forests alternating in places with peculiar shrub formations or leafless grass plants of the meadow type (Petkov and Pacharazov, 1988).

In the past decade the flora of the salt meadows near the town of Radnevo has not been a subject of a special study. We find data about their vegetation in some works on the halophylic vegetation in Bulgaria from the second half of the 20th century (Ganchev and Kochev, 1962, Ganchev et al., 1971) and the beginning of the 21st century (Tzonev et al., 2008).

The present investigation is part of a research project for studying the Inland salt meadows' flora near the town of Radnevo and the aim was to investigate the relationship between soil salinity and the vascular plants in the studied area.

## MATERIALS AND METHODS

The survey was conducted in 2011 – 2012. The location map of the study area and sampling points are shown on Figure 1. A total of 60 soil samples were taken from a depth of 0-20 cm. In each sample taking point the vascular plants existing there were also collected. Soil samples were analyzed for Electrical conductivity (EC) and pH. Soil pH was determined on air-dry samples using 1:2.5 soil : water ratio. Electrical conductivity ($\mu S.cm^{-1}$) was measured using 1:5 soil:water ration and used as an indicator of salinity (Popandova, 1995, 2001).

The following were used as taxonomic basis for determining the species adherence of the collected plants: The Flora of PR Bulgaria (Jordanov, 1963–1979; Velčev, 1982, 1989; Kožuharov, 1995), Field Guide to the Vascular Plants in Bulgaria (Kozhuharov, 1992), Key to the Plants of Bulgaria (Delipavlov and Cheshmedzhiev, 2003).

Chemometrics was used to establish relations between the soil properties and distribution of the vascular plants in the the studied Inland salt meadows. Principal component analysis (PCA) was applied to the experimental data to assess relationship between values of EC and pH in soil samples and distribution of the samples in multimensional space. Cluster analysis (K-means methodology) was performed to understand the distribution of vascular plants with regard to values of EC and pH of soil samples. Chemometrics was carried out by Unscrambler X 10.2 (CAMO Software AS, Norway).

## RESULTS AND DISCUSSIONS

The values of EC in the studied soil samples were characterized with wide range from 75.0 to 2057.0 $\mu S.cm^{-1}$, with SD = 366.0. According to the soil saltiness scale (Trendafilov and Popova, 2007) 85.0% of the samples were classified as not saline and 15.0 % were classified as saline. Most of them were light saline – 10.0% ($800 < EC < 1400$ $\mu S.cm^{-1}$) and only 5.0% of all samples were moderately salty soils ($EC > 1400$ $\mu S.cm^{-1}$), The distribution of values of EC and pH in studied soil samples are presented in Figure 2 and 3, respectively.

According to values of pH ($H_2O$) most of the samples – 91.7% were characterized with alkaline reaction and the remaining samples with neutral reaction. The mean value of pH was 7.5 and SD was 0.39. Alkaline reaction and high values of EC in saline soils were mainly due to the presence of sulfates. Carbonates were not established in the soil.

On the base of values of EC and pH for soil samples were performed Principal component analyses to investigate the soil samples distribution in multimensional space (Figure 4). In the score plots, the grouping of objects can be recognized (Simeonov et al., 2010).


Figure 1. Location map of the study area and sampling points

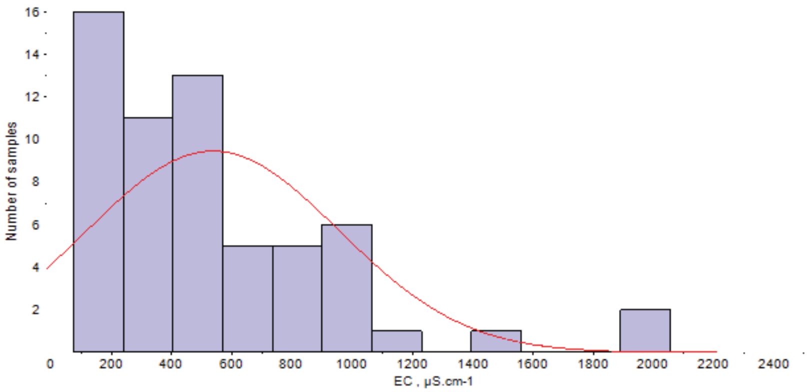


Figure 2. Histogram of EC values, µS.cm-1 in studied soil samples

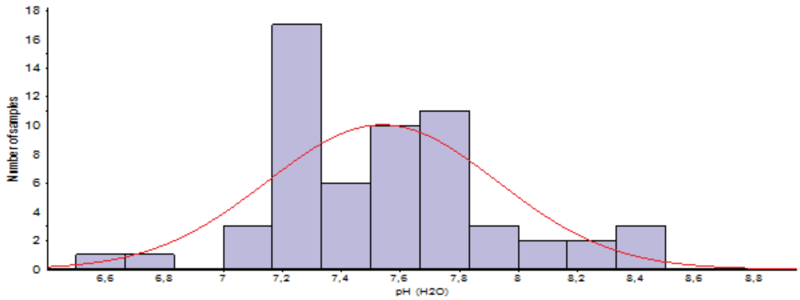


Figure 3. Histogram of pH values in studied soil samples

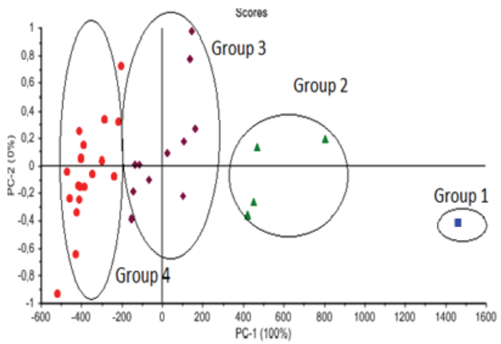


Figure 4. Scores plot of the soil samples

Factor 1 explained 100% of data variance, separated four groups of soil samples clearly. PC1 completely described variable – soil electrical conductivity, therefore EC is dominant soil parameter for groups formation than pH. Group 1 occupied distinctly different area in multimensional space far from others. The soil samples belongs to that were moderately salty with EC from 2050 to 2057 $\mu S.cm^{-1}$. Group 3 and Group 4 formed two groups at a short distance for each other. It is not surprising because samples of that two groups are non-saline with EC from 444 to 730 and from 123 to 356 $\mu S.cm^{-1}$, respectively. Group 2 occupied an area between Group 1 and the others. Soil samples belonging to that group were slighly saline with EC from 1014 to 1402 $\mu S.cm^{-1}$. On the basis of PC analysis result non-hierarchical clustering via K-means methodology was applied to group vascular plants based on their similarity with regard to the studied soil properties. Four clusters (groups) were specified in advance.

As a result of the conducted floristic studies during the vegetation period of 2011-2012 a total of 112 species of vascular plants have been found in the studied territory. The present analysis includes the 57 species registered during sample taking. The results about grouping of the studied vascular plants according to soil properties are presented in Table 1.

Predominant among them are the representatives of *Poaceae* and *Cyperaceae* families. Group 1 comprises 9 species occurring at EC from 2012 to 2057, $\mu S.cm^{-1}$ (Table 1). Five of these – *Carex distans* Host., *Elymus elongatus* (Host.) Runemark, *Hordeum hystrix* Roth and *Taeniatherum caput-medusae* (L.) Nevski are among the species registered with the most numerous populations in the studied territory and one – *Rorippa sylvestrys* (L.) Besser is of the species represented by the least numerous populations. Seven of the plant species included in group 1 incl. the five species represented by the most numerous populations and the two species of the genus *Trifolium -T. repens* L. and *T. resupinatum* L. are among the ones mentioned by Tzonev and Gussev (2011) as characterizing the inland salt meadows taxa. The other two species of Group 1– *Carex divisa* Huds and *Rorippa sylvestrys* are mentioned by Delipavlov and Cheshmedzhiev (2003) for saline locations in various parts of the country.

In Group 2 there are 17 species registered at EC from 695 to 1065, $\mu S.cm^{-1}$. The most numerous populations during the study have been found for six species – *Carex distans*, *Juncus gerardii* Loisel, *Elymus elongatus, Hordeum hystrix,Taeniatherum caput-medusae, Mentha pulegium* L. The first five species plus 4 more of the species included in that group-*Cynodon dactylon* (L.) Pers, *Dianthus campestris* Willd., *Trifolium repens* and *Trifolium resupinatum* are among the ones mentioned by Tzonev and Gussev (2011) as characterizing inland salt meadow taxa. The last species-*Mentha pulegium* is pointed out by Ganchev et al. (1971) as an accompanying species in grass communities formed in depression areas on medium and slightly saline soils. A part of the other representatives of group 2 such as *Alopecurus genuculatus* L., *Bromus commutatus* Guss. ex Steud, *Carex divisa,* etc. are hygrophytes tolerant to moderate soil salinity, another part such as *Pulicaria vulgaris* Gaertn and *Ranunculus constantinopolitanus* d' Urv are ruderal plants tolerant to slight soil salinity.

In group 3 there are a total of 30 species of vascular plants distributed at EC from 356 to 529, $\mu S.cm^{-1}$), and in Group 4 there are a total of 27 species distributed at EC from 75-307, $\mu S.cm^{-1}$) (Table 1). The most numerous populations of plants included in the two groups during the study have been registered for *Carex distans, Elymus elongatus, Hordeum hystrix, Bolboschoenus maritimus* Palla, *Ranunculus aquatilis* L., *Butomus umbellatus*

L. The first three species were mentioned by Tzonev and Gussev (2011) as characterizing inland salt meadows. The other three species- *Bolboschoenus maritimus, Butomus umbellatus* and *Ranunculus aquatilis,* as well as the greater part of vascular plant species included Group 3 and Group 4 such as *Alisma lanceolatum* With., *Leersia oryzoides* (L.) Sw., *Lemna minor* L., *Poa palustris* Vohlleb., *Rumex palustris* Sm., etc. are taxa typical of swampy and marshy areas. Their occurrence in the studied territory is accounted for by the considerable soil dampness during the greater part of the year since a salt meadow occurs together with a swamp. The other part of plants included in these two provisional groups are predominantly xerophytic and ruderal species. Their participation in the grass cover is due to the prolonged drought of part of the meadow during the hot months of the year.

Ten of the 57 vascular plant species included in the present study were registered in samples of varying EC range (Figure 5). Four of them – *Taeniatherum caput-medusae, Trifolium repens, Elymus elongatus, Cynodon dactylon* have been found at locations with varying salinity level from slight to medium. Six species – *Carex divisa, Hordeum hystrix, Alopecurus geniculatus, Bromus commutatus, Carex distans* and *Trifolium resupinatum* have been registered both on saline and non-saline soils.

## CONCLUSIONS

The data in the present study show that in the inland salt meadow near the town of Radnevo there is different salinity level – from non-saline to medium saline. The salinity process results from the high level of underground water, the plain relief and the micro-depressions on its territory. The reaction of the studied soil samples is from neutral to medium alkaline, predominant are the samples with alkaline reaction.

A dominating factor for the grouping of the found 57 vascular plant species as a result of the applied cluster analysis is the electroconductivity of soil samples. Ten samples of the studied vascular plants- *Taeniatherum caput-medusae, Trifolium repens, Elymus elongatus, Cynodon dactylon, Carex divisa, Hordeum hystrix, Alopecurus geniculatus, Bromus commutatus, Carex distans* and *Trifolium resupinatum* have been registered in samples with different EC range, the last six species were found on non-saline and saline soils. Nine species – *Carex distans, Cynodon dactylon, Elymus elongatus, Hordeum hystrix, Taeniatherum caput-medusae, Trifolium repens, Trifolium resupinatum, Dianthus campestris* and *Juncus gerardii* are among the taxa mentioned as characterizing Inland salt meadows in Bulgaria.

The most numerous in the studied territory are the populations of *Carex distans, Elymus elongatus, Hordeum hystrix, Taeniatherum caput-medusae, Juncus gerardii*, *Bolboschoenus maritimus, Ranunculus aquatilis* and *Butomus umbellatus*.

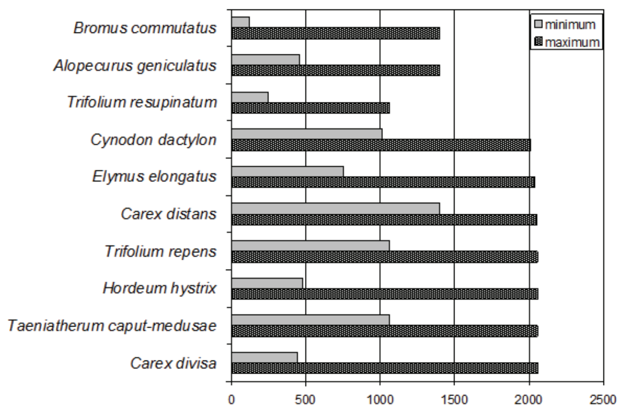

Figure 5. Vascular plant species found in samples of different salinity level

Table 1. Cluster analysis of the studied vascular plants based on values of EC and pH in the measured soil samples

| Soil parameters | Group 1 | Group 2 | Group 3 | Group 4 |
|---|---|---|---|---|
| pH | 7.3-7.5 | 7.2-7.8 | 7.4-8.5 | 6.5-8.2 |
| EC, $\mu S.cm^{-1}$ | 2050-2057 | 1402-1014 | 756-444 | 356-123 |
| | *Carex distans* Host. | *Alopecurus geniculatus* L. | *Carex divisa* Huds | *Alisma lanceolatum* With. |
| | *Carex divisa* Huds | *Bromus commutatus* Guss. Ex Stend | *Alisma lanceolatum* With | *Bolboschoenus maritimus* Palla |
| | *Cynodon dactylon* (L.) Pers. | *Carex distans* Host. | *Alopecurus geniculatus* L. | *Bromus arvensis* L. |
| | *Elymus elongatus* (Host) Runemark | *Carex divisa* Huds | *Alopecurus pratensis* L. | *Bromus commutatus* Guss. Ex Steud. |
| | *Hordeum hystrix* Roth | *Cynodon dactylon* (L.) Pers. | *Atriplex hastata* L. | *Bromus secalinus* L. |
| | *Rorippa sylvestris* (L.) Besser | *Dianthus campestris* Willd. | *Beckmannia eruciformis* Host | *Butomus umbellatus* L. |
| | *Taeniatherum caput-medusae* (L.) Nevski | *Elymus elongatus* (Host) Runemark | *Bolboschoenus maritimus* Palla | *Carex acutiformis* Ehrh. |
| | *Trifolium repens* L. | *Hordeum hystrix* Roth | *Bromus commutatus* Guss. ex Stend. | *Centaurea calcitrapa* L. |
| | *Trifolium resupinatum* L. | *Juncus gerardii* Loisel | *Carex distans* Host | *Dischanthium ischaemum* (L.) Roberty |
| | | *Lysimachia nummularia* L. | *Carex hordeistichos* Vill. | *Eleocharis palustris* (L.) Roem. & Schult |
| | | *Mentha pulegium* L. | *Carex vulpina* L. | *Festuca erundinacea* Vill. |
| | | *Persicaria mitis* (Schrank.) Opiz | *Convolvulus arvensis* L. | *Juncus effuses* L. |
| | | *Pulicaria vulgaris* Gaertn | *Coronopus procumbens* Gilib. | *Lemna minor* L. |
| | | *Ranunculus constantinopolitanus* d Urv | *Datura stramonium* L. | *Lycopus exaltatus* L. |
| | | *Taeniatherum caput-medusae* (L.) Nevski | *Elymus elongatus* (Host) Runemark | *Mentha longifolia* (L.) Huds. |
| | | *Trifolium repens* L. | *Galium octonarium* (Klokov) Soó | *Oenanthe silaifolia* M. Bieb. |
| | | *Trifolium resupinatum* L. | *Hordeum hystrix* Roth | *Persicaria mitis* (Schrank.) Opiz |
| | | | *Leersia oryzoides* (L.) Sw. | *Plantago major* L. |
| | | | *Lolium perenne* L. | *Poa bulbosa* L. |
| | | | *Lysimachia nummularia* L. | *Poa compressa* Schrenk ex Ledeb. |
| | | | *Medicago arabica* (L.) Huds. | *Poa palustris* Vohlleb. |
| | | | *Mentha longifolia* (L.) Huds. | *Pulicaria vulgaris* Gaertn. |
| | | | *Oenanthe silaifolia* M. Bieb. | *Ranunculus aquatilis* L. |
| | | | *Poa bulbosa* L. | *Ranunculus lanuginosus* L. |
| | | | *Poa compressa* Schrenk ex Lebed | *Ranunculus lateriflorus* DC. |
| | | | *Poa palustris* Wohlleb | *Ranunculus sardous* Crantz |
| | | | *Poa pratensis* L. | *Rumex palustris* Sm. |
| | | | *Poa sylvicola* Guss. | |
| | | | *Rumex palustris* Sm. | |
| | | | *Veronica anagallis-aquatica* L. | |


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