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Relationship between soil salinity and Bassia hirsuta, Salicornia europaea agg. and Petrosimonia brachyata distribution on the territory of Pomorie lake and Atanasovsko lake

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Abstract. In the Black Sea biogeographical region on the territory of Bulgaria there are only two Salinas – Atanasovsko lake and Pomorie lake. Since 1980 the northern part of Atanasovsko lake has been declared nature reserve. Since 1999 the northern part of the lake has been re-categorized as Managed Nature Reserve according to the new Protected Areas Act. Since 2001 Pomorie lake has been declared Protected Site. The aim of the study was to assess the relationship between soil salinity and halophyte plants distribution – Salicornia europaea agg., Bassia hirsuta (L.) Asch. and Petrosimonia brachiata (Pall.) Bunge on the territory of both protected areas. The period of investigation was between September and October, 2013. A total of 22 soil samples were taken from a depth of 0 – 20 cm. In each sample taking point vascular plants of Salicornia europaea aggr., Bassia hirsuta and Petrosimonia brachiata existing there, were also collected. The collected soil samples were analyzed for electrical conductivity (EC), pH, Cl , CO and HCO content. The soil from the studied territory of Atanasovsko lake Managed Nature Reserve was characterized with alkaline to strong alkaline reaction and high level of salinity. The alluvial deposit from Pomorie lake Protected Site was characterized with neutral to alkaline reaction and light to high salinity. Salicornia europaea forms populations on alkaline soil, with salinity from 2 to 44 mS/cm, but dominates on high salinity soil, above 14 mS/cm. Bassia hirsuta forms populations on soil with neutral to moderate alkaline reaction and from light to high salinity, with EC up to 14 mS/cm. Petrosimonia brachyata forms populations on alkaline soil, from light to moderate salinity, with values of EC from 2 to 6 mS/cm.

Keywords: electrical conductivity, soil salinity, salinas, Salicornia europaea aggr., Bassia hirsuta, Petrosimonia brachyata

Introduction

Salt and alkaline lakes could be found on every continent. Within salt lakes, alkaline wetlands form a hydro chemically distinct group. They include numerous large lakes, but the majority are shallow, often seasonal still wetlands. Bare, dry lakebeds are characterized by scattered, annual halophytic plants (Boros, 2003). A halophyte is a plant that completes its life cycle in a salty environment and shows optimal growth in the presence of very high concentration of salt. Some of these halophytes have specialized morphological adaptations to cope with high salinity, such as glandular hairs or succulence (Zörb et al., 2013). On the other hand, the large majority of plant species, which include all major crop plants are damaged by salinity (Penkov et al., 1985; Zaprianova et al., 2007; Zörb et al., 2013)

In the Black Sea biogeographical region on the territory of Bulgaria there are only two Salinas – Atanasovsko Lake and Pomorie Lake. The objects of our study were soil salinity and distribution of halophytes Salicornia europaea agg., Bassia hirsuta (L.) Asch. and Petrosimonia brachiata (Pall.) Bunge on the territory of both lakes. The northern part of the Atanasovsko lake has been declared Nature Reserve (State gazette, № 70/1980). Since 1999 the northern part of the lake has been re-categorized as Managed Nature Reserve according to the new Protected Areas Act (1998). Atanasovsko ezero is hyper saline near the coastline, divided in two parts by the road Bourgas – Varna. Both parts of the lake have been salt-pans since 1906. The lake level is about 1 m lower than the sea level. Pomorie lake is a natural hyper-saline lagoon, being part of the most significant complex of wetlands along the Bulgarian Black sea coast – Burgas Wetlands. It is separated from the Black Sea by a sand bar. Since 2001 Pomorie lake has been declared Protected Site.

The climate in the study area is continental-Mediterranean. The absolute maximum of temperature exceeds 40°C, while the absolute minimum is ~ 20.3°C (Tsenkova-Bratoveva et al., 2010). The average precipitation value is between 520 and 580 mm. The highest values are reached in June and November, and the lowest – in August and September. The annual average air temperature is 12 – 13°C, and the temperature in January varies between 20.5 – 21.5°C.

There are many publications found in the literature about the vascular plants in Pomorie lake Protected Site and Atanasovsko lake Managed Nature Reserve (Grozeva, 2004, 2005; Grozeva et al., 2004; Stojanov, 2010), but a few of them reported controversial results about the relationship between soil salinity and halophyte plant distribution. For instance, Ivanova et al. (2006) reported soil salinity in the sand bar near Pomorie lake from 659 to 850 mg/g which values are too low for halophyte plants from Bassia, Petrosimonia, Salicornia, whereas Süm er et al. (2010) reported that species from genus Salicornia grow well at 70 g/l dissolved solids.

The present study attempts to answer two main questions: 1. Is there any difference of level of salinity between the territories of Atanasovsko and Pomorie lakes which are inhabited by communities of annual halophytes from Bassia hirsuta, Petrosimonia brachiata, Salicornia europaea aggr., 2. Does soil salinity level influence the distribution of those halophytes.

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Material and methods

Sample collection

The period of investigation was between September and October, 2013. The location maps of the studied areas and sampling points of Pomorie lake and Atanasovsko lake are shown on Figure 1. A total of 22 soil samples were taken from a depth of 0 – 20 cm. In each sample taking point the plants from Bassia hirsuta, Petrosimonia brachiata, Salicornia europaea agg. existing there were also collected. Soil samples were air-dried and then passed through a sieve with a 2 mm mesh. 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. EC (mS/cm) was measured using 1:5 soil water ratio and used as an indicator of salinity (Popandova, 2001). The level of salinization was evaluated according to values of EC, mS/cm (Table 1). Determination of Cl, CO$_3$$^-$$^-$ and HCO$_3$$^-$$^-$ content was performed according to classical chemical methods. Content of SO$_4$$^{2-}$ was determined by UV/VIS spectrophotometer DR 5000 Hach Lange (Germany).

To assess the status of the population of Bassia hirsuta, Petrosimonia brachiata, Salicornia europaea agg. methodology for monitoring vascular plants in Bulgaria has been used. The voucher specimens are deposited in the herbarium of the Institute for Biodiversity and Ecosystem Research, Bulgarian Academy of Sciences (SOM). Chemometrics was used to establish relations between the soil properties and distribution of the vascular plants in the studied areas. Principal component analysis (PCA) was applied to the experimental data to assess the relationship between values of EC and pH in soil samples and distribution of the samples in multidimensional space. Chemometrics was carried out by Unscrambler X 10.2 (CAMO Software AS, Norway).

Results and discussion

Soil salinity in both protected areas

The descriptive statistics of values of the EC for the soil samples from the territory of Pomorie lake Protected Site and Atanasovsko lake Managed Nature Reserve are presented on Figure 2. According to the soil saltiness scale the samples were classified as different level of salinization from light to high saline. A difference of the level of soil salinity between both studied areas was found. For instance, soil samples from the territory of Atanasovsko lake are characterized with more salinization than samples from the territory of Pomorie lake. The minimum values of EC 1.78 mS/cm of samples from Pomorie lake were lower than the minimum values of EC in samples from Atanasovsko lake with EC 2.59 mS/cm. The same trend was found with average and maximum values. The mean values of electrical conductivity of the soil samples from the area of Atanasovsko lake were two times greater than those for the samples from Pomorie lake. The maximum value of EC (42.6 mS/cm) of the samples from Atanasovsko lake area was much higher than that of Pomorie lake samples, EC=12.61 mS/cm.

The studied territory of Atanasovsko lake is occupied by Lake Solonchaks, which are characterized by water dissolved salts content with high level of salinity (Trendafilov, 2001). Therefore, the soil samples from Atanasovsko lake were characterized by alkaline reaction with values of pH (H$_2$O) between 8 and 9.2 in comparison to the samples from Pomorie lake with values of pH (H$_2$O) between 7.1 and 8.9, which characterized the neutral to alkaline reaction of the samples (Figure 3).

A correlation between EC and values of pH in the samples from the present study with R = 0.60 was found. Alkaline reaction and high values of EC in saline soils were mainly due to the presence of water-

Figure 1. Location map of studied area and sampling points from the territory of Pomorie lake Protected Site and Atanasovsko lake Managed Nature Reserve.
typically contains 40 grams per liter (g/l) of dissolved salts, mostly sodium chloride. Kolev et al. (2013) reported that the surface ion concentrations of salts evaporated from Black sea water were with higher values of Cl = 47.40 at,% as compared to HCO = 2.09 and CO = 0.26 at,%. The main reason of salinity in the studied areas was capillary rise from high ground water due to sea water influence. Evaporation of water by capillarity resulted in salt accumulation on the soil surface (Sümer et al., 2010).

Based on the data for chloride content in the samples, the chloride concentrations in the samples from the Atanasovsko lake area were higher than Pomorie lake, the ranges were between 3.8 and 21 meq/100 g and between 2.7 to 9.5 meq/100 g, respectively (Figure 4).

By increasing the chloride content, the EC values of soil solution also increased.

Relationship between soil salinity and halophyte plants distribution

On the territory of Pomorie lake the population of Bassia hirsuta is characterized by the greatest number and area, whereas in the researched areas of the Atanasovsko lake Salicornia europaea agg. is dominating. Populations of Petrosimonia brachiata are limited in number and area.

On the basis of the values of EC and pH for soil samples Principal component analyses were performed to investigate the soil samples distribution in multidimensional space (Figure 6). In the score plots, the grouping of objects can be recognized. Factor 1 explained 93% of the data variance, and formed clearly one group of soil

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samples. PC1 completely described variable – soil electrical conductivity, therefore EC is the more dominant soil parameter for group formation than pH. Soil samples belonging to that group are characterized by light to high salinity, with EC values between 2 – 14 mS/cm and with neutral to moderate alkaline reaction with pH values between 7.1 – 8.9. Under these soil conditions the dominant species was *Bassia hirsuta*. There is the second scattered group of samples in the PCA space with five soil samples with alkaline soil and high soil salinity from 6 to 44 mS/cm. Under these soil conditions the dominant species was *Salicornia europaea* agg. Figures 7 and 8

**Figure 5.** Relationship between Cl, meq/100 g content and EC values in the soil samples.

**Figure 6.** Score plot of the soil samples on the first two principal components according to values of pH and EC.
Figure 7. Distribution of *Bassia hirsuta*, *Petrosimonia brachiata* and *Salicornia europaea* agg. according to EC values in the soil samples.

Figure 8. Distribution of *Bassia hirsuta*, *Petrosimonia brachiata* and *Salicornia europaea* agg. according to pH values in the soil samples.
graphically illustrate the distribution of Salicornia europaea agg., Petrosimonia brachiata and Bassia hirsuta according to EC and pH (H₂O) values in soil samples. The species from genus Salicornia form a population in the soil salinity from 2 to 44 mS/cm and is predominant in salinity above 14 mS/cm. According to the present study, Petrosimonia brachiata grew in the slight saline soils on both of the studied territories with EC values from 2 to 6 mS/cm. Therefore, halophytes such as Salicornia europaea agg. and Bassia hirsuta form populations in different soil salinity level. Sümer et al. (2010) also reported that species from genus Salicornia as Salicornia fragilis survive in higher soil salinity than Petrosimonia brachiata. The authors pointed higher values of EC = 67.62 and 49.13 dS/m as compared to the data in our study. Zörb et al. (2013) brachiate. survive in higher soil salinity than Salicornia fragilis (2010) also reported that species from genus Bassia hirsuta could be grown on soil with neutral to moderate alkaline reaction. Petrosimonia brachiata and Bassia hirsuta could be grown on soil with neutral to soil with low soil fertility. Zemizdat, 2007. The flora of the Pomoriysko lake Protected Site – In: Collection of Scientific Reports of Exerts, BSPB. Sümer A, Sungur A, Karabacak E and Özcan H, 2010. The soil from the studied territory of the Managed Nature Reserve near Atanasovsko lake is characterized by high level of salinity and alkaline to strong alkaline reaction. The studied alluvial deposit from the territory of Pomoriysko lake Protected Site is characterized by light to high salinity and neutral to alkaline reaction. Salicornia europaea agg. forms populations in Pomoriysko lake Protected Site and Atanasovsko lake Managed Nature Reserve on alkaline soil, with salinity from 2 to 44 mS/cm, but dominates on high salinity soil, above 14 mS/cm. Bassia hirsuta (L.) Asch. forms populations in both protected areas on soil with neutral to moderate alkaline reaction and from light to high salinity, with EC up to 14 mS/cm. Petrosimonia brachiata forms populations in both lakes – Pomoriisko and Atanasovsko on alkaline soil, from light to moderate salinity, with values of EC from 2 to 6 mS/cm.

Acknowledgements

This work was supported financially by Project № 2E/13 Trakia University, Faculty of Agriculture.

Conclusions

The soil from the studied territory of the Managed Nature Reserve near Atanasovsko lake is characterized by high level of salinity and alkaline to strong alkaline reaction. The studied alluvial deposit from the territory of Pomoriysko lake Protected Site is characterized by light to high salinity and neutral to alkaline reaction. Salicornia europaea agg. forms populations in Pomoriysko lake Protected Site and Atanasovsko lake Managed Nature Reserve on alkaline soil, with salinity from 2 to 44 mS/cm, but dominates on high salinity soil, above 14 mS/cm. Bassia hirsuta (L.) Asch. forms populations in both protected areas on soil with neutral to moderate alkaline reaction and from light to high salinity, with EC up to 14 mS/cm. Petrosimonia brachiata forms populations in both lakes – Pomoriisko and Atanasovsko on alkaline soil, from light to moderate salinity, with values of EC from 2 to 6 mS/cm.

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