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Adaptable Features of Annual Halophytes to the Conditions of Arid Zones and the Prospects for their Potential Use to Global Warming and Biotechnology

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Abstract: In the agenda for the 21st century much attention is paid to the study of arid ecosystems and restoration of degraded ecosystems. Species adapted to arid conditions have a dominant role in the vegetation of the arid zone. Annuals of the *Chenopodiaceae* family belong to this species. Based on the adaptive characteristics the species is divided into ecologic groups: hyperxerophyte and euxerophyte. The hyperxerophyte group has all-round adaptability that includes reduced assimilative organs, high specialization, deep penetrating root system, well-balanced aquatic regime indices. According to their characteristics, the hyperxerophyte group is divided into subgroups: succulents and sclerophyte. *Climacoptera lanata* (Pall.) Botsch., *Salsola paulsenii* Litv., *Salsola.sclerantha* C. A. Mey being in the first group, *Girgensohnia oppositiflora* (Pall.) Fenzl. in the second, and the last one having sclerophylic structure and less stable aquatic regime. *Ceratoecarpus utriculosus* Bluk. belongs to the euxerophyte group, having a strongly pronounced biological adaptability that includes advanced growth phase, feebly marked early ontogeny stages, and replacement of laminate spring leaves by needle-shaped ones. Their aquatic regime is labile. This plant is very adaptable to drought and salinity, as hyperxerophyte and hypergalophyte. Hyperxerophytes and hypergalophytes - *Climacoptera lanata* (Pall.) Botsch., and others, have potential for surface improvement of degraded pastures as drought-resistant plants and decrease the amount of salt in the soil. They also can be used for biotechnology purposes and sustainable development.

Key Words: Halophyte, Hypergalophyte, Hyperxerophyte, Xerothermic period

1. Introduction

Due to global warming increasing desertification, degradation of vegetation, and soil salinity impacted by the Aral Sea, the study of the adaptive features of summer vegetation plants of arid zones of Central Asia is very important.

Species with a wide range of biological, morphological, and ecological adaptive traits play a dominant role in the vegetation of arid zones. The annual halophytes are one of these dominate plant species. Water relations of plants, in combination with their structural and functional features, often limit viability in arid zones. Among the adaptive features of the annual thistle are the type of root systems, the power of their development, the ability for the reduction of the leaf blade, and the relationship of indicators of water requirements which play a special role. Research by Grigoriev (1950) in Tajikistan, Rahimova (1975) in the Kyzyl-Kum, Rahimova (1195-1997) in the Fergana adyrs and Butnik (1983) in the Kyzyl-Kum have been dedicated to the study of adaptive characteristics of arid zone plants.

2. Materials and Methods

The objects of our research were representatives of hyperxerophytes: *Climacoptera lanata* (Pall.) Botsch.; *Salsola paulsenii* Litv.; *S. sclerantha* C. A. Mey.; *Girgensohnia oppositiflora* (Pall.) *Fenzl*.; and the euxerophyte *Ceratoecarpus utriculosus* Bluk.

A comparative study of indices of water regimes, content of water in the assimilative organs (by gravometrical method) (Nichiporovich, 1926), intensity of transpiration (Ivanov *et al.*, 1950), water deficit (Shatckiy, 1960) and osmotic pressure (Gusev, 1960) was conducted. The soil moisture was taken into account up to 150 cm depth by Rode's method (1969).

Study areas are the Chust-Pap and Chartak adyrs of Ferghana Valley, which are in close proximity to the desert climate. The study area experienced a dry summer, wet spring and fall, of short duration, but a rather severe winter. The Chust-Pap adyrs are the most arid. In this area, rainfall averages 168 mm/year according to long-term data. Long-term data indicate an average temperature of 14.1ºC and an absolute maximum of 45ºC, with an absolute minimum of -28ºC. Relative humidity is 58%. Soil is light gray with stony-gravelly, texture developed on loamy-gravelly

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sediments.

In the Chartak adyrs average temperature is 12.9ºC, with an absolute maximum of 40ºC. The relative humidity is 63.7% with an average yearly rainfall of 243.8 mm. Soils of this area are typical gray soils and light gray soils from coarse to fine textured, slightly saline. For every 100 cm of soil layer, the moisture content in soil from April to July decreases from 4.2% to 1.7%.

3. Results and Discussion

The studied plants are distinguished by the structure of the leaves and the types of the root system:

- *Ceratoecarpus utriculosus* Bluk. has lanceolate leaves 3-3.5 cm long and up to 3 mm in width, with needle-like shoots on top. In the hot season lanceolate leaves dry and remain needle-shaped. The root system is of the stick-type weakly branched, up to 70-80 cm in depth.
- *Girgensohnia oppositiflora* (Pall.) Fenzl leaves - in April, leaves are 3 cm in length, by summer they are dry. The root system is of the stick-type to fly up to, up to 135 cm in depth.
- *Salsola sclerantha* C. A. Mey leaf size varies from 10 mm to 0.5 mm from April to mid-summer and leaves are lanceolate-shaped. The root system in July is up to 90-100 cm in depth and of the rod type.
- *Salsola paulsenii* Litv. leaves per stem range from 5-6 cm, they decrease closer to the top of the shoot. The root system of the stick-type reaches 130-150 cm in depth, with 5-6 lateral roots.
- *Climacoptera lanata* (Pall.) Botsch- leaves are up to 1-1.5 cm long. A.A. Butnik notes: "That the early development of the plant leaf traces in the axis is one way to adapt to environmental conditions seedlings". The shoot of the mature plant reaches up to 35 cm; the root system is of the rod type with a depth up to 180-200 cm.

In analyzing of the performance of the water relations of studied annuals it is revealed that *Climacoptera lanata* (Pall.) Botsch and *Salsola paulsenii* Litv exhibited the most stable and high water content in the assimilation shoots during the growing season. The highest average daily values of water content in *Climacoptera lanata* (Pall.) Botsch is 86.5%, and 81.4% in *Salsola paulsenii* Litv. in April, and the lowest average daily rates in August at -75%. The lowest water content during the season occurs in *Ceratoecarpus utriculosus* Bluk: from 71% in April to 30.2% in August average per day. *Salsola.sclerantha* C. A. Mey and *Girgensohnia oppositiflora* (Pall.) Fenzl., are in an intermediate position. Comparison of transpiration showed that the types differ in the frequency of occurrence of the most common values. The most economical consumption of water by transpiration differs in *Climacoptera lanata* (Pall.) Botsch with 95% of units with low transpiration - from 0 to 300 mg / g h ; above 400 mg / g h transpiration rate is not found. *Salsola.sclerantha* C. A. Mey's transpiration rate was from 0 to 300 mg / g h and occured in 82% of cases. For *Salsola paulsenii* Litv. and *Girgensohnia oppositiflora* (Pall.) Fenz., these rates are found only in 43-45% of cases, and in some cases transpiration rate reached up to 800 mg / g h. *Ceratoecarpus utriculosus* Bluk had the highest level of the process: the rate of transpiration from 0 to 300 mg / g h occurs in 38% of cases and higher values up to 1600 mg / g h were observed. Thus stable and low seasonal variation transpiration was observed in *Climacoptera lanata* (Pall.) Botsch and *Salsola sclerantha* C. A. Mey. It is less stable in *Salsola paulsenii* Litv., and *Girgensohnia oppositiflora* (Pall.) Fenzl., The highest rate of transpiration occurs in *Ceratoecarpus utriculosus* Bluk.

The excess water consumption over absorption leads to recurrent water scarcity in transpiring plant parts. Water scarcity indicates the degree of resistance of plants to drought. The lowest water deficit was observed in *Climacoptera lanata* (Pall.) Botsch, *Salsola paulsenii* Litv. From spring to summer, water increases only slightly, from 9.9% to 17.4% in *Climacoptera lanata* (Pall.) Botsch, and from 11.7% to 20% on average per day in *Salsola paulsenii* Litv.. *Girgensohnia oppositiflora* (Pall.) Fenzl. and *Salsola.sclerantha* C. A. Mey.'s water deficit is significantly higher, from 11.7% to 28% on average per day which results in a significant drying of the leaves in the summer. The highest rates of water deficit occur in *Ceratoecarpus utriculosus* Bluk. As early as April, the deficit is 18%, and with the onset of xerothermic period it rises up to 52%.

According to the osmotic pressure of the studied species the following patterns are observed: *Climacoptera lanata* (Pall.) Botsch, *Salsola paulsenii* Litv., and *Salsola sclerantha* C. A. Mey. grow from spring to summer slightly (6-20 atm); *Girgensohnia oppositiflora* (Pall.) Fenzl. has a higher performance from 9-30 atm. A significant increase in osmotic pressure occurs in *Seratoecarpus utriculosus* Bluk., from 9-33 atm.

Water-holding capacity is one of the universal indicators of a plant's resistance to drought. It should be noted that in all studied species, except *Seratoecarpus utriculosus* Bluk, water holding capacity increases from spring to summer. A significant increase in water retention was observed in *Girgensohnia oppositiflora* (Pall.) Fenzl. In the three other species water retention was consistently high and increases slightly. In *Seratoecarpus utriculosus* the reverse process takes place (*i.e.* water-holding capacity decreases from spring to summer.)

In the mathematical analysis of various indicators of water regime: water content (WC), water-holding capacity (WHC), transpiration rate (TR) and the osmotic pressure (OP)) determined the correlation coefficient between them. According to **Figure 1**, in the spring for *Climacoptera lanata* (Pall.) Botsch an inverse relationship can be seen between WC, TR and OP. At high water contents low transpiration and slight osmotic performance were observed. In the summer months, with a decrease in WC, TR is reduced, but the water deficit and osmotic rates rise. Increasing the osmotic pressure leads to an increase in retention capacity. The correlation shows that the basis of the stability of the water relations of drought in *Climacoptera lanata* (Pall.) Botsch is a close correlation between water content, water retention, and osmotic pressure.

There is a direct relationship between WC and TR of *Salsola paulsenii* Litv, *i.e.* in spring with a high WC we see a high TR, and in summer with a decrease of WC, a reduction of TR is observed. The inverse relationship exists between WC, OP and WHC. With a decrease of WC the osmotic pressure, water-holding capacity, and water scarcity increase. There is a high correlation (0.9), between WHC and WC, WHC and TR, WHC and OP of *Salsola paulsenii* Litv. Water-holding capacity of the plant is also a determining factor in the regulation of water relations.

There is an inverse relationship between the WC and TR of *Salsola sclerantha* C. A. Mey, (*i.e.* high in WC assimilation shoots and low TR , as well as low Water deficit and OP). In summer, with a WC decrease, water deficit increases and TR is slightly lower. There is an inverse relationship between the WC and WHC. As WC increases, WHC rises, leading to a decrease in TR. Between water deficit and OP there is a direct relationship and increasing water deficit causes an increase in osmotic indicators. The high coefficient of correlation was observed between TR, OP and WHC, and also between the WHC and other indicators.

Girgensohnia oppositiflora (Pall.) Fenzl's water content is slightly lower than the above species. Despite this, in spring TR is relatively high, *i.e.* there is a direct relationship. Water deficit and osmotic indicators were also higher with an inverse relationship with relatively low WHC. By the summer, water content and transpiration is reduced - there is a direct correlation between these parameters. Water deficit and osmotic rates rise significantly, leading to an increase in water-holding capacity. Between the WHC and TR there is a close correlation. And also there is a close correlation between the WHC and the OP, WC and TR, and OP and TR. That is, the regulation of the water relations in these species is due to an increase of the WHC and OP for the summer.

Ceratoecarpus utriculosus Bluk differs from other species.

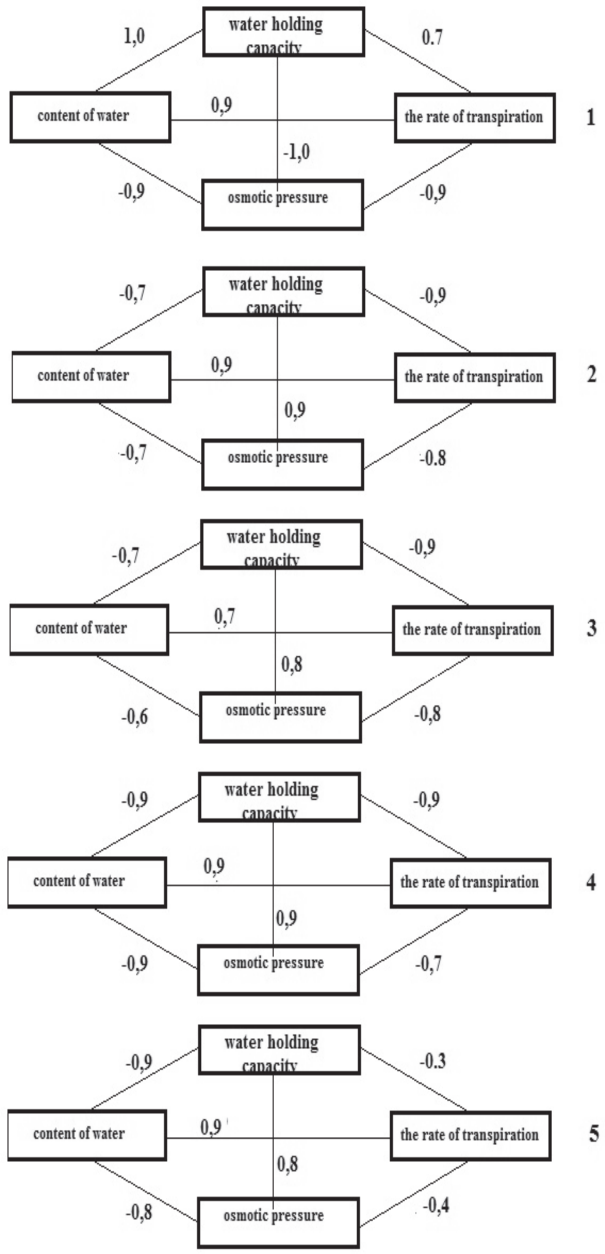

Fig. 1. The relationship of indicators of water relations (the numbers indicate the correlation of water regime).
1- *Ceratoecarpus utriculosus* Bluk
2- *Girgensohnia oppositiflora* (Pall.) Fenzl
3- *Salsola.sclerantha* C.A. Mey
4- *Salsola paulsenii* Litv
5- *Climacoptera lanata* (Pall.) Botsch.

At relatively slight water content there is a high TR. The high water deficit and OP are inversely related to the low WHC. With decreasing water content in summer the TR falls. The water deficit and OP continue to rise, while the WHC is reduced. A high coefficient of correlation is observed between the WC and WHC, WC and OP, WHC and TR.

As observed, decreases in water content cause the tension of other indicators of water regime. In the studied species a number of common features of adaptation are revealed:

- the rapid penetration of the root system into the deep soil

in the early stages of ontogeny. If the plant height is 3-4 cm , the root is 10 times or more greater than its height for the fastest achievement of the moist soil horizons;
- reduction of transpiring ability or replacement of large leaves with smaller leaves in order to reduce the surface area of evaporation;
- the balanced water relations and the close correlation between the indices in hyper xerophytes and biological adaptation in euxerophytes.

4. Conclusions

Our research revealed the following:
- The studied annual halophytes are adapted to the arid conditions through structural functionality and biological characteristics.
- The complex adaptive traits of the studied annual thistles indicate potential for their use in improving the surface of degraded pastures.
- Productivity of the studied species depends on the conditions of meteorological communities and the abundance of super organisms up to 15 centner per hectare.

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