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"Screening and pilot planting of halophytes for combating soil salinization in Central Asia"

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I. Executives Summary

The Aral Sea region, which is known as an area of ecological disaster, comprises about 50 million ha of Kazakhstan, Uzbekistan and Turkmenistan territory and is populated by more than 3 million people. Pastures occupy up to 20 million ha, while most of the remaining area is irrigated agricultural fields. All irrigated lands are secondary salinized at different rates. The second major factor of land degradation in the region is desiccation of more than 40,000 km^2 of the Aral Sea coast and the maritime parts of the Amudarya and Syrdarya rivers' delta. The territory of the dried sea bed has been transformed into solonchaks. About 1.5 million metric tons of salt from the dried off sea bottom are blown by winds towards populated areas and agriculture lands annually. As a result, the quality of the plant breeding and livestock breeding products is decreasing, and the living conditions and health of the local population are deteriorating.

Methods currently applied to reclaim salt-affected irrigated lands (drainage, soil washing, etc.) are inefficient and their effects are, at best, transient. They result mainly in spatial redistribution of the salts, rather than their removal from the ecosystem. In our opinion, there is an urgent need for the other approaches to combat soil salinization - approaches that will prevent anthropogenic desertification and allow improvement, stabilization and long-term utilization of currently salinized soils. One such approach is the introduction and cultivation of halophyte plant species that may i) improve soil properties, such as mineral and organic content; ii) re-colonize and grow successfully in poor/deteriorated soils with limited or no irrigation; iii) possess high agricultural, pharmaceutical or recreational value. Halophytic plants are known to be effective against shifting sands, by reducing winds and accumulating salts.

The main goal of the proposed research was to creation of a halophyte genebank and development of halophyte-based agriculture in the Aral Sea region by irrigation of halophytes with brackish water.

More specifically: 1) to create a halophyte germplasm collection in Kazakhstan and Uzbekistan comprised of valuable varieties and cultivars; 2) to study the agricultural properties and adaptability to saline soil conditions of selected halophyte species; 3) to develop halophyte propagation, planting and bioremediation technology specific for particular soil types and salinization histories (saline moving sands, degraded pastures on sandy and sandy-loam soils, on clay and sandy-clay soils).

As a result of this project, at the first step the selected halophyte species were evaluated experimentally under brackish and salty water irrigation; at the second step the best performing species were tested in the field on the dry bottom of Aral Sea; and the next tasks of proposed study were development of methods of seed storage, germination, nursery management and propagation of the best performing species and monitoring of halophyte plantations. The results of this research will make it possible to determine the best ways of soil preparation, methods of sowing on sandy and salty soils, seed treatment and seeding rates, the optimal nutritive and irrigation regimes, the experimental ground and principles and different placing in systems of halophyte irrigated agriculture. The results of ridge planting of *Haloxylon aphyllum* and *Salsola richteri* shrubs and *Ceratoides papposa* semishrub on bare solonchaks of the dried-out floor of the Aral Sea with minimum irrigation with waste waters or without it can be considered satisfactory. However, the shrub halophytes achieve best development and adaptability on non saline soil with irrigation with fresh waters. *Haloxylon aphyllum* plantings under natural conditions on solonchaks of the dried Aral Sea bed endure a moisture deficit from a decrease in atmospheric precipitation better than *Salsola richteri* plantings.

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Effect of the temperature, sodium chloride and its various concentrations on the seed germination of the some halophyte were studied. In result the optimum temperatures of seeds germination and limit them salt tolerant are determined.

Within the framework of the project is created halophyte genebank, which will be filled up at the expense of the expedition collection of germplasm and exchange seeds. An annotated bibliography of the relevant literature on halophyte agronomy and utilization is made and scientists of the target countries are transferred.

II. Research Objectives

Salinity is a major concern to agriculture all over the world because of the wide distribution of salt-affected soils on all continents that covers about 10% of the total dry land surface. Salt-affected soils in North and Central Asia occupy more than 200 million ha, which are about 20% of the total area of such soils in the world (Szabolcs, 1994). In the former Soviet Union, many large-scale irrigation projects for the establishment of rice- and cotton-based agriculture were started in arid regions in Central Asia in the 1960s. Poor irrigation practices and improper drainage systems have resulted in salinization of millions of hectares of farmlands in that region. According to Rozanov (1984), one million hectares of land has been already lost in Central Asia due to erroneous irrigation practices.

The region surrounding the Aral Sea coastline (called the Priaralye) has been acknowledged by the worldwide scientific community as a global ecological catastrophe. The main causes of the ecological and economic crisis in the Aral Sea region are the programmed regulation of the flow of the Amudarya and Syrdarya Rivers during the drought of the 1970s. Consequently, the water level of the Aral Sea declined and its salinity increased, leading to the emergence of a new sand desert of about 40,000 km^2 (Babaev, 1996). The negative consequence of lowering the Aral Sea level, land degradation, caused by desertification, in this type of land has led to the reduction of pasture areas, deterioration of fodder crops quality and, finally, to decrease in animal husbandry productivity. The dry sea bottom is the main factor of desertification in the region. Sand, salt and dust are blown by winds towards the populated areas and agricultural lands. Per year approximately 1,5 million metric tons of salt from this former sea bottom, spread by winds, contributes to salinization of the surrounding land.

Moreover, the growing volume of drainage water, a direct consequence of increasing and extensive irrigation, has lead to a decline in the quality of drinking water, ground water and river water. More than 30 km^3 of drainage water flow from the irrigated areas of the Aral Sea Basin to the rivers, to adjacent territories and to desert pastures per year.

The existing methods for reclamation of salt-affected irrigation lands (drainage, soil washing, etc) are not efficient enough since they result only in spatial redistribution but not removal of the salts from the biological cycle of the regional ecosystem. Therefore combating soil salinization is an important part of a strategy for prevention of anthropogenic desertification. One new approach to solving this problem is an introduction of halophyte species to such regions. Cultivation of halophytes is a promising approach to reclamation of salt-affected soils and use of poor arable lands, especially in situations where the fresh water supply is limited or does not exist. Halophytes can

tolerate environmental extremes with respect to both drought and salinity and, therefore, are great candidates for reclamation of salinized soils and sand stabilization.

The most salt-tolerant halophytes are classified as euhalophytes (Glenn et al., 1999). Many of these species can complete their entire life cycle on seawater salinities. Many halophytes also have tolerance to waterlogged soils, a common problem in salinized irrigation districts (Flowers and Colmer, 2008) Many halophytes also have tolerance to waterlogged soi, a common problem in salinized irrigation districts. Field trials have shown that the same agronomic methods developed for handling salinity problems for conventional crops can be applied to halophyte crops (Glenn et al., 1999), but with a much higher salinity threshold. Numerous agronomic studies have been conducted with halophytes that establish the feasibility of treating them as irrigated or dryland crops (Alsaeedi and Elprince, 2000; Carter et al., 2005; Suyama et al., 2007). Similarly, euhalophytes grown on seawater (> 32 ppt) require a leaching fraction of the same magnitude to maintain high productivity (Glenn et al., 1997; Elhaddad and Noaman, 2001). However, when euhalophytes are grown on brackish water of lower salinity, the leaching fraction can be reduced to < 5% (Jordan et al., 2009). Many halophytes are also drought-tolerant, and they can be deficit irrigated to prevent discharge of saline water to the aquifer (Glenn et al., 2009). Halophytes can be used within irrigation districts to absorb saline drainage water from conventional crop production that would otherwise need to be discharged to receiving water bodies or the aquifer (Grattan et al., 2008).

Relevant to the situation in Central Asia, halophytes have been used in California's Central Valley as part of a cascade of increasingly salt tolerant crops, to minimize the amount of drainage water that must ultimately be discharged (Grattan et al., 2004; Qadir et al., 2007; Wilchelns and Oster, 2006). A cascade can include conventional crops such as vegetables, cotton, grains and alfalfa, followed by salt-tolerant forage grasses and shrubs (Khan et al., 2009; Suyama et al., 2007). The cascade concept works in the Central Valley because drainage tubes have been installed throughout the fields. Subsurface drainage water is collected in sumps, from which it can be recovered and reused for subsequent more tolerant crops. Ultimately, a small volume of highly saline water (ca. 80-100 ppt) is collected for evaporation to dryness in ponds. In Australia, a similar cascade can be implemented without the need for subsurface drain systems. Low spots in and around the farm fields (typically wheat or other grains) are planted with halophyte shrubs (e.g. native *Atriplex* spp.) that help control the water table, which is saline and damages crops when it rises into the root zone. (Barrett-Lennard et al., 2005). This same concept can be extended to other irrigation districts with salinity and drainage problems to create sustainable cropping systems.

Halophytes can also be used to absorb saline effluent generated by aquaculture projects (Brown and Glenn, 1999). Aquaculture effluent is usually enriched in nutrients, which can support halophyte crops. On the other hand, when this effluent is discharged directly to the ocean or other receiving bodies, it can produce eutrophication and can spread viral diseases if repumped for aquaculture. Halophytes can also be used to absorb saline water generated by industrial processes such as desalinization plants and cooling towers at electric generation facilities (Glenn et al., 1998). Halophytes can also be used for phytoremediation of nitrates (Jordan et al., 2008) and heavy metals (Ghnaya et al., 2007), and for remediation of degraded soils (Keiffer and Ungar, 2002; Marcone, 2003; Sargeant et al., 2008).

In Central Asia, scientific work on the use of halophytes for rehabilitation of degraded lands and increasing their productivity has been done in two directions. The first one involved reclamation of degraded natural arid pastures using halophytes without irrigation. This work resulted in identification of 15 perspective species of halophytes and development of preliminary technologies

of their cultivation (Nechaeva, 1985). The second direction involved search for halophytes as potential fodder crops for cultivation, under irrigation with salty water of different origin and salinity (sea, drainage, and underground water). This program has been initiated, and the experimental fieldwork has been set up (Shevelukha, Shamsutdinov, Nazaryuk, Orlovsky, 1992), but the program was halted with the disintegration of the USSR.

The proposed research was been carried out in the Kyzylorda district of Kazakhstan and the Karakalpakistan region of Uzbekistan. Both of these districts are situated in the Aral Sea region. This region has considerable economic importance for Kazakhstan and Uzbekistan. Irrigated agriculture and cattle breeding are widespread. The Aral Sea region in resent years became the area of ecological disaster. The greatest ecological problems of this region are: 1) intensification of secondary salinization processes on irrigated land, 2) loss of lands' natural and effective fertility, and 3) degradation of desert pastures and sedimentation of salts carried away from the desiccated bottom of the Aral Sea.

Saline soils and halophytic vegetation are typical for the Central Asia. In the Aral Sea Basin, within the short time of about 40 years, the development of a huge, new salt desert has taken and is still taking place, caused by the drying of the Aral Sea. The area of saline soils on the dry sea floor amounts to about 40 thousand square km. Additional areas with saline soils is found within the irrigation zones. These secondary salinized soils have an area of about 22 thousand square km (Glazovsky and Orlovsky, 1996). This means that in a relatively short time period, within less than a half century, the area of salt deserts in Central Asia has grown by about 62 thousand square km. The dry sea floor is covered with a mixture of shells, clay, loam, sand and salt.

While there is a significant deficit of fresh water in the lower reaches of the Amudarya River for irrigation and human needs, the volume of slightly salinized drainage water (up to 5 g/l) is more than 5 cubic km/year. This volume of water is being diverted to the depressions in the desert or flows to the neighboring pastures. This process results in water logging, salinization of desert pastures and degradation of natural vegetation. The level of salinity of the drainage water is less than that of the seawater used for cultivation of fodder halophytes (Aronson et al, 1988; Glenn and O'Leary, 1985). The drainage water could, thus, be a significant additional source for growing salt-tolerant species, and therefore could be successfully used for additional fodder production and reclamation of secondary salinized lands.

The main objectives of the proposed research was to creation of a halophyte genebank and development of halophyte-based agriculture in the Aral Sea region with irrigation by brackish water.

Specifically the goals are:

a) to create halophyte germplasm collection in Kazakhstan and Uzbekistan;

b) to study the agricultural properties and adaptability to high salinity of selected halophyte species, both indigenous and originating in other parts of the world, from the U.S.A and Israel halophyte collections;

- to develop halophyte propagation, planting and bioremediation technology specific for particular soil types and salinization histories (saline moving sands, degraded pastures on sandy and sandy-loam soils).

III. Methods and Results

III.1. Sowing and planting of annual and perennial halophytes species in different parts of the Aral Sea region

For the experiments on artificial formation of pastures lands were selected in the Mo'ynoq area located 6 km north of the settlement Mo'ynoq on the Aral Sea bed that dried up in the 1990s, in the former Rybatskii Bay with gently rolling marine sand deposits whose surface for all practical purposes is not stabilized. Pedogenic processes in the plot are developing in an automorphic regime with ground waters at a depth from 5 to 8 m.

Some plots in two areas of Karakalpakstan have been broken: in Mo'ynoq district - on salonchaks the dried bottom of the Aral Sea and in Mo'ynoq district - on slightly saline sandy loam soils on a shore of strongly salted Lake Solenka (Fig. 1).

. Fig. 1. Location of test areas in the Southern Pre-Aral region. Sites 1 and 2.

1) Entirely the site on salonchaks the dried bottom of the Aral Sea in Mo'ynoq district for plantings one year seedlings *Haloxylon aphyllum.* The size of site is 1.3 hectares (the control and testing). Series on the separate small area (20 m x20 m) were sowing seeds *Salsola richteri* and *Haloxylon aphyllum.* The site for cultivation of annual plants here ranged (the control and testing), it compounded approximately 40 m x 40 m. Having watered this site spent fire pump vigor of 800 l/mines. Water from the tail drain had in 300 m from a site, with a water salinity of 2.5-3.5 g/l was used.
2) In Nukus district was sowing for cultivation annual and perennial grasses. Its general size (the control and testing) has compounded 20 m x 50 m. For convenience watering and observation

inside it has been divided into squares on 5 m x 5 m. The site poured down slightly saline (1.5-2.0 g/l) and not salted (1.0-1.2 g/l; SW Lake Grachevka) water which delivered to a place by cars.

Sowing and planting of annual grass – *Climacpotera aralensis, Kochia iranica, Salsola nitraria,* of shrubs – *Haloxylon aphyllum, Salsola richteri, Calligonum caput-medusae, Tamarix hispida,* and semishrub *Ceratoides papposa* are being tested.

For the control over dynamics of humidity and salts in soils the sampling both on sites of planting and were taken. In total 68 soil profiles by depth from 1.5 m up to 3 m. has been made. Because of a heavy mechanical makeup of soils (clay and loams) the sampling took from the holes dug manually depth of 1 m with the subsequent boring in them up to 3 m. In total 679 sampling of soils and irrigation waters for carrying out of chemical analyses on a salinization (water extract), acidity (pH), electroconductivity and humidities are taken.

Measuring instrument Combo HI 98130 for the analysis of water and soils on a level pH (hydrogen potential), total of soluble salts (ppt) and specific electroconductivity (EC) in December 2007 has been purchased. In total for 2008 it is processed by device Combo HI 488 samples of ground, and 51 samples of water (including 122 samples of water and soils for years 2006 and 2007). On them are already preliminary conclusions were done.

For check of data on temperature and humidity of air, and also for registration of temperature and humidity of soil on different depth automatic registrars – termogigrohromes have been purchased. The information is kept on the chip inside of registrars and transferred to a computer at single scan data by the autonomous portable device - IB-Flash. One logger (for definition of temperature and humidity of air) has been installed in settlement Mo'ynoq in corresponding conditions on a private site of one of participants of the project. The second logger has been installed directly on experimental site in a shadow of large bush *Haloxylon aphyllum.* Other measuring devices (2 loggers, and 7 registrars: 5 – termogigrohromes and 2 termohrones) have been installed in various soil horizons of experimental sites. Installations on continuous registration of temperature and humidity in each 4 hours per the nearest 1.5 years are executed. The autumn of 2008 (the middle of October) had been removed the first indications from devices.

The size of the general salinization of separate horizons of soils on experimental site of drying bottom land of Aral Sea (Mo'ynoq area) changes very quickly and strongly (from 1.5 up to 3 times) as year by year, and from a season by a season. Especially strongly it changes on a site with watering.

On experimental site in Nukus area the size of the general salinization soils varies not so considerably as year by year, and from a season by a season. Probably it is connected with general lower salinization of irrigation water in Nukus area, and also with sandy structure soils of site.

To prevent the abundant appearance of annual species of halophytes *(Salsola* spp., *Suaeda* spp.), which suppress shrub seedlings, as well as the formation of a salt crust after copious precipitation, deep plowing of the territory and laying out rows were carried out. Each ridge was separated by a depth of 30-45 cm for collecting abnormally high precipitation and accomplishing summer irrigation. The distance between ridges was 2 m, single plant specimens were also planted along the ridge every 2 m. Shrubs were planted on December on April 2006, on April 2007, on December 2008, by hand, using forestry-raised year-old *Haloxylon aphyllum* and *Salsola richteri* planting stock (the seedlings were grown on weakly saline soils) and *Calligonum caput-medusae* cuttings; after heavy rains, the semi shrub was planted by seeds along earlier prepared ridges. The seed material (of *Ceratoides papposa, Climacpotera lanata, Kochia iranica, Salsola orientalis)* was collected in the fall of 2005, 2006, and 2007 in the region of conducting the works.

Planting of plants *Haloxylon aphyllum* on site 1) was spent seedlings in the age of 1-st year, bought in a pilot farm of Karauzjak district. Seedlings have been cultivated without watering on not salted flushed loamy alluvial meadow soil at a constant groundwater table of 1-1.5 m. By our earlier researches it has been established, that the most seedlings in height up to 10 cm do not get accustomed. Therefore we used basically middle seedlings, by height 15-40 cm.

During 2006-2008, watering with a total volume of 1670-1700 m^3/ha was done twice: in the middle of May and start of July with water that had a salinity of 1.9-2.3 g/l of the magnesium-potassium chloride-sulfate type. However, the water being supplied to the plot was barely retained in the inter rows and seeped along deep undermining cracks and depressions into the lower-lying soil horizons, leaving the upper 0.3-0.5 m practically dry. Such a structure of the solonchak plains of the former sea bed of the Aral is related to the character of desiccation of the territory as well as to the underlying parent material. Thus, moistening of the ridges directly was possible only due to capillary rise of water from lower-lying horizons.

As rule in April-May when it is spent having watered crops, water in the channel near experimental site in Mo'ynoq area does not exceed 2 g/l. At the same time, in the middle of summer the salinization in the channel on site of plantings can reach 12.9 g/l (on August, 23rd, 2006). However, at this time having watered plantings it is never carried out. During spring May repeated inspection sites of plantings in Muynak area the salinization in the channel from which irrigation water undertook are 2.73 g/l (5/3/2008). Thus, it on 30% exceeded usual size of salinization of irrigation water in Muynak area for this season. So, on May, 06th, 2006 the salinization waters in the same channel was 1.93 g/l, and on May, 15th and 25, 2007 it made 2.13 and 2.14 g/l. Irrigation water for a site in Nukus area undertakes usually from the Lake Grachevka located near to of Nukus or from a water pipe of Nukus. Salinization in Lake Grachevka during the spring period (April-May) makes usually also size less than 2 g/l (1.69 g/l – 4/5/2007; 1.43 g/l – 4/13/2007; 1.41 g/l – 5/7/2006). In May, 2008 salinization here has made 2.25 g/l. Substantial increase of salinization in irrigation water is connected with a drought in Uzbekistan in 2008.

In Muynak area in 2006-2008 the general salinization of surface irrigation water in the channel near to experimental site also strongly varied year by year and from a season by a season. The size salinization of waters in the channel changes much more strongly (in 4-7 times), than salinization in soil horizons of experimental site.

On sites 1) and 2) hydro gel Stockosorb has been used. Beads Stockosorb dissolved in buckets in a proportion 150 g of materials on 10 l of waters. Then the dissolved hydro gel admixed with soil in a proportion of 2 buckets of a hydro gel on 8 buckets of soil before reception wet ground-soil mass. The received wet edaphic mass with a hydro gel of 35-40 cm and width 30 cm x 30 cm brought in hollows, for plantings seedlings *Haloxylon aphyllum.* At planting by seeds, all quantity of seeds brought in the received edaphic mass. Then it spread on garden-beds, depth no more than 2-3 cm. From above all sprinkle a flake of primary soil.

Last two years, despite of all undertaken efforts on watering and planting annual plants in Mo'ynoq area results of works extremely weak and unstable. At the same time, even in own private enterprises of Mo'ynoq area (at two-multiple daily watering: in the morning and in the evening) last two years it is not possible to grow up any annual cultures, and, practically all fruiters have completely dried up.

a) Results of experimental landings of annual grasses

In a vegetative period for annual grasses *Salsola orientalis* and *Climacoptera lanata* the height (cm), a projective density (%), numbers of specimens (psc.) plants and productivity for 16 sites in the dimension 1 m^2, had in area Nukus were analyzed: 4 control sites – without watering and without a hydro gel, 4 plots with watering and without a hydro gel, 4 sites without watering and with a hydro gel, 4 sites with watering and with a hydro gel.

The first experiments has shown, that on lower salted sandy deserted soils the use of hydro gel increases average height of plants *Salsola orientalis* both at watering and without watering (Fig. 2; Table 1).

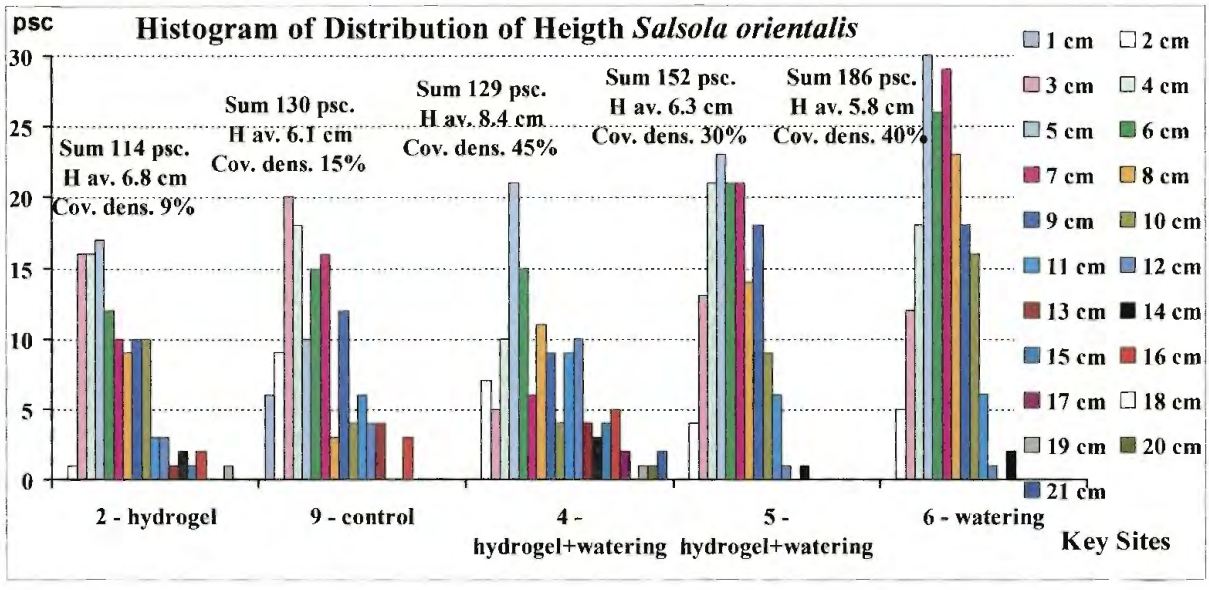

Fig. 2. Histogram of Distribution of Heigth *Salsola orientalis,* Nukus area, 25.05.2008.

In the spring (on May, 25th 2008) on sites without watering the average height of plants with a hydro gel (on a modeling site 2-hydro gel) was more on 10% and reached 6.8 cm, while in the control (a site № 9-control) it reached only 6.1 cm (Fig. 2). On sites with watering in the spring the average height of plants with a hydro gel was more on 22% and making 7.4 cm, while without watering and without a hydro gel – only 5.8 cm (Fig. 2).

By the autumn influence of a hydro gel on height of plants has shown more considerably. In the autumn season for plots without watering the average and minimal height of plants *Salsola orientalis* (on the average for 4 sites) was more approximately twice (in 1.8 times or on 44% for average height and in 1.9 times or on 46% for the minimal height of plants) for sites with a hydro gel (min=13 cm, average=24.6 cm) in comparison with sites without a hydro gel (min=7 cm, average=13.8 cm; Table 1); while their maximal height differed not strongly – on 19% (36 cm and 29 cm; Table 5).

In the autumn influence of a hydro gel on sites with watering was not so appreciable, as on sites without watering. The hydro gel at watering has increased average height of plants *Salsola orientalis* only by 30% (35.3 cm and 25.5 cm), the minimal height – only 14% (21 cm and 18 cm), and here maximal – on the whole of 45% (65 cm and 36 cm in the autumn; Table 1).

Table 1. The basic biometric parameters of the planted plants (quantity of specimen, height and diameter, weight crude and air-dry over ground phytomass, a cover density in % for community) on modeling sites in the end summer-autumn the period (on October, 07th, 2008) in Nukus district of Karakalpakstan.

Name of plant species	Watering	Hydro gel	Number of sites	Size of site, m^2	Number of plants	Cover Density, % (for $10m^2$)	Height, cm			Diameter, cm			To mow	
							min	average	max	min	average	max	Damp Weight, g	Dried Weight, g
Annual grasses														
Salsola orientalis	without	without	4	1	33	25	7	13.8	29	-	-	-	188	81
S. orientalis	without	with	4	1	27	35	13	24.6	36	-	-	-	214	104
S. orientalis	with	without	4	1	10	45	18	25.5	36	-	-	-	325	167
S. orientalis	with	with	4	1	10	65	21	35.3	65	-	-	-	422	280
Climacoptera lanata	without	without	4	1	8	20	10	18.5	25	7	14.4	24	517	183
C. lanata	without	with	4	1	9	45	28	41	46	38	42	48	1250	443
C. lanata	with	without	4	1	5	75	33	36.8	43	30	38.2	44	3500	1242
C. lanata	with	with	4	1	6	95	25	29.8	41	21	31.5	42	4250	1508
Perennial grasses														
Ceratoides papposa	without	without	4	1	4	25	34	45.5	58	27	40.8	55	483	220
C. papposa	with	without	4	1	7	50	14	30.4	61	12	28.7	47	1250	602
C. papposa	with	without	4	1	7	55	12	41.3	62	15	40.4	73	1500	710
Alhagi pseudalhagi	without	without	4	1	4	15	57	59.8	65	34	44.8	57	750	388
A. pseudalhagi	with	without	4	1	5	65	66	82.8	94	25	50.2	70	1250	647
A. pseudalhagi	with	without	3	5	16	35	42	68.9	98	11	36.1	70	no data	no data
A. pseudalhagi	without	withaut	3	5	25	45	18	34.4	52	12	25.8	43	no data	no data
A. pseudalhagi	without	without	3	5	40	55	18	39	60	12	29.1	52	no data	no data

In the spring on sites with a hydro gel without watering the part of high plants - i.e. with height from 3 up to 10 cm was above than on a control site – without a hydro gel and without watering. The same time at watering the basic part of plants fell to heights from 5 cm up to 12 cm (Fig. 2).

Thus in the spring-summer season influence of a hydro gel on a projective density on modeling sites with *Salsola orientalis* showed slightly or did not come to light at all as without watering (with a hydro gel without watering – 9%, the control without a hydro gel without watering – 15%), and with watering (without a hydro gel with watering – 40%, with a hydro gel with watering – 30-45%; Fig. 2). Essential influence on projective density *Salsola orientalis* both in vernal-years and in the autumn season rendered only having watered plants. So on May, 25th, 2008 the projective density of grasses on sites with watering reached 30-45% (sites 4, 5-hydrogel+watering, a plot 6 watering; Fig. 2) while without watering it reached only 9-15% (a site № 9-control, a site № 2-watering; Fig. 2). Much greater influence watering in comparison with a hydro gel has noted been as well in the autumn season (Table 1). So on October, 07th, 2008 influence of a hydro gel on modeling sites with *Salsola orientalis* variated an average projective density (for each 4 areas in the dimension 1 m^2) the areas without watering poorly – only to 10% (Table 1). While having watered increases a projective density twice (by 20% on sites without a hydro gel: from 25% up to 45% and on 30% on plots with a hydro gel: from 35% up to 65%; Table 1). Thus, results of researches have shown, that having watered in all seasons of a vegetative period are increased of projective density *Salsola orientalis* twice. At the same time influence of a hydro gel on augmentation of a projective density can be estimated no more than 6-10%. However these data require check. As lay within the limits of an admissible error of measurements.

It is established, that in the spring the numbers of specimen of plants *Salsola orientalis* and *Climacoptera lanata* on sites without hydro gel above as without watering(on 12% for *Salsola orientalis,* 130 psc. and 114 psc., Fig. 2; and on 43% or in 1.8 times for *Climacoptera lanata,* 151 psc. And 86 psc., Fig. 3) and at watering (on 24% for *Salsola orientalis,* 186 psc. And 140.5 psc., Fig. 2) in comparison with sites with hydro gel. However in the autumn the picture changes. At watering the numbers of specimen of plants on sites with hydro gel and without it equal (10 for *Salsola orientalis;* 5-6 for *Climacoptera lanata;* Table 1). Hydro gel at watering does not reduce the numbers of specimen of plants in the autumn, but increases habit of plants (i.e. height, diameter and productivity; Table 1).

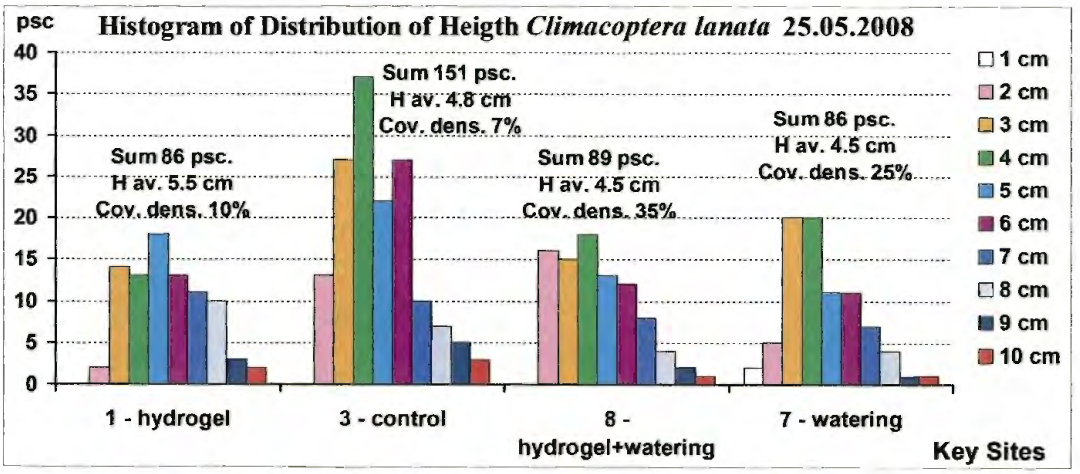

Fig. 3. Histogram of Distribution of Heigth *Climacoptera lanata,* Nukus area, 25.05.2008

Productivity *Salsola orientalis* at influence of watering (without influence of hydro gel) increases on the average 2 times as in moisture (in 1.7 times or on 42 %, 188 g and 325 g; Table 1), and in dry weight (in 2.1 times or on 51%, 81 g and 167 g; Table 1). Positive influence of hydro gel on productivity *Salsola orientalis* very weak as without watering (increase on 12 %, 214 g and 188 g; Table 1), and at watering (increase on 23%, 422 g and 325 g; Table 1).

Continuation of researches with *Climacoptera lanata* in 2008 also was confirmed with earlier conclusions for this species of a plant (2005-2007). In spring-years the season having watered *Climacoptera lanata* does not increase height of plants (4.5 cm at watering, 4.8-5.5 cm without watering; Fig. 3), total of plants on a site (86-89 pieces/specimen at watering, 86-151 pieces/specimen without watering; Fig. 3); only projective density (25-35 % with watering, 7-10% – without watering increases; Fig. 3). It speaks about increase in the spatial sizes of the plants which have appeared on a site. The greatest positive influence of hydro gel on height, diameter and productivity of plants *Climacoptera lanata* is shown on sites without watering. Without watering with hydro gel the height and diameter of specimen of plants increase in 2 and more times (Table 1). Productivity of plants *Climacoptera lanata* in the autumn at influence watering without influence of hydro gel appears approximately in 6.8 times more, than without watering, as in moisture (517 g and 3500 g), and in dry weight (183 g and 1242 g). While at watering hydro gel poorly increases productivity - only on 18% or in 1.2 times as in moisture (4250 g and 3500 g), and in dry weight (1508 g and 1242 g).

On solonchaks on dried bottom of the Aral Sea the basic limiting factor at vegetation annual plants it is necessary to consider not a salinization, but humidification of the upper soil horizons. Humidity of the first 0-10 cm automorphic solonchaks the dried bottom of the Aral Sea in vegetative period does not exceed 4-5%. The compound and constitution of soil-ground does not allow is long to increase humidification of surface soil layers even at watering. Periodic 5 - multiple watering for two months (April-May, 2007) could not increase humidification automorphic solonchaks of drain bottom Land of Aral Sea for normal germination of seeds of annual grasses (*Kochia iranica, Climacoptera aralensis, C. lanata, Salsola orientalis, S, nitraria)* and *Ceratoides papposa.* The same time, at constant soil humidification on meadow solonchaks and on slightly saline automorphic soils in Nukus region there are 100%, 65% and 55% accordingly. At equal severe salinization (above 1.5% on solid residue) surface soil layers and various humidification germination the same species differs in 65-120 times. Thus, without artificial maintenance of humidification in surface soil layers of soil recultivation automorphic solonchaks in modern climatic conditions (with the tendency to magnification of heat and decrease of rainfall in the summer-autumnal season) is not possible.

B) Results of experimental landings of perennial grasses

Besides of annual plants in Nukus area on March, 28th, 2008 were sowing of perennial grasses *(Alhagi pseudalhagi* and *Acroptilon repens)*, being good pastoral plants (Photo 1). On 6 standard areas 5x5 $м^2$ with watering 48 specimens of plants *Alhagi pseudalhagi* (from 40 up to 56 pieces) were totaled on the average. Their height on sites has made: average – 49 cm (from 31 up to 42 cm), max – 57 cm (from 52 up to 65 cm), min – 17 cm (from 12 up to 23 cm). On 6 sites without watering 19 specimens of plants *Alhagi pseudalhagi* (from 19 up to 21 pieces) were totaled on the average. Their height reached: average - 33 cm (from 32 up to 36 cm), max – 49 cm (from 42 up to 56 cm), min – 19 cm (from 17 up to 20 cm). Thus, with watering the quantity of plants *Alhagi pseudalhagi* has increased in 2.5 times, their average height has appeared above in 1.5 times, and the maximal height has increased on 16% (Photo 2).

a)

b)

Photo 1. Height finding of *Acroptylon repens* in Nukus area 04 May 2008: a) on site without watering., b) on site with watering.

a)

b)

Photo 2. Height finding of *Alhagi pseudalhagi* in Nukus area 04 May 2008: a) on site with watering, b) on site without watering.

The measurement of *Acroptilon repens* has shown following. On 6 standard areas 5x5 $м^2$ with watering we have counted in average 79 specimen of plants of *Acroptilon repens* (from 52 to 115 pcs). Their heights on sites are: in average – 35 cm (from 31 to 41 cm), max – 64 cm (from 58 to 72 cm), min – 13 cm (from 5 to 20 cm). On 6 sites without watering counted in average 57 specimen of plants of *Acroptilon repens* (from 45 to 78 pcs.).Their heights have reached: in average 34 sm (from 33 to 35 cm), max – 60 cm (from 50 to 77 cm), min – 15 cm (from 8 to 21 cm). With watering the number of plants *Acroptilon repens* to increase on 39%, their average height was higher on 3%, and maximal height to increase on 7% (Photo 1). Thus the watering of site with *Acroptilon repens* to influence only on number of plants and their projective cover which to increase from17 to 35%.

At watering on sites with *Alhagi pseudalhagi* considerably increases the projective density in average in 2.6 times (from 1.4 up to 4.7 times; sites 14, 15, 13, 12, 10 with watering, in comparison with sites 17, 16, 18 – without watering; darkly green curve, Fig. 4), and numbers of specimen of plants increases in average in 1.9 times (from 1.4 up to 2.1 times; a violet curve, Fig. 4). The average maximal and minimal height of plants thus decreases on 10-20% (green, red, dark blue curves, Fig. 4).

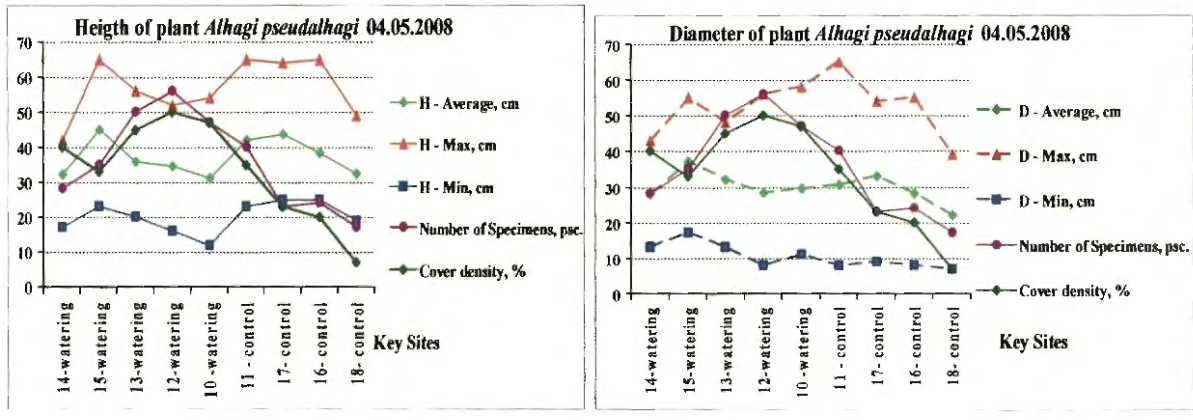

Fig. 4. Height and diameter of plant *Alhagi pseudalhagi* 04. May 2008, Nukus area.

Thus, having watered on sites with *Alhagi pseudalhagi* increase the spatial sizes (diameters of over-ground part) greatest and least specimen of plants in average on 10% (5-30%) and 50% (10-90%) accordingly, not influencing on average values of diameters (Fig. 4).

As have shown autumn measurements of the basic biometric parameters of plantings of annual and perennial grasses (Table 1), their production basically depends from watering and to a lesser degree on influence of hydro gel. At watering the dry weight of the oblique grasses increases on modeling site in 1.5-3 times for sites with watering in comparison with the control. Besides it both for annual, and for perennial grasses at watering the quantity of specimen of plants on a modeling site decreases, but their sizes both on height, and on diameter increase, thus the general projective density on the modeling site (Table 1) considerably increases. Weak influence of hydro gel is connected, most likely, with strong saline of soils.

An analysis of the multiyear mode of growth of semi shrub *Ceratoides papposa* plants showed that their height and viability were higher on the plot without irrigation, as was seed germination (by 2-4 times). The survival rate of 2-year-old plants out of the number of those recorded at an age of 6 months was about equal for both plots (20% and 21.3% in 2005; 15.8% and 16.4% in 2006; Table 2).

During the next years, after ending irrigation the results of the *Ceratoides papposa* sowing experiments on the control plot and with irrigation became practically equal both with respect to survival rate (15.8%, 4.2% – with watering and 16.4%, 2.5% – without watering) and plant growth (average =18.2-45.6 cm, max=36-67 cm, min=9-32 cm – with watering; and average =14.2-35.7 cm, max=40-50 cm, min=7-12 cm – without watering).

Index	**Live plants**				
Month, Year	*11.2004*	*04.2005*	*11.2005*	*05.2006*	*10.08*
Age, years	0.5	1.0	1.5	2.0	4.5
Without watering (control)					
Height, cm					
minimum	5.0	5.0	11.0	7.0	12.0
average	13.3	13.4	21.8	14.2	35.7
maximum	27.0	25.0	39.0	40.0	50.0
Survival, %	55.0	73.8	21.3	16.4	2.5
With watering					
Height, cm					
minimum	5.0	5.0	11.0	9.0	32
average	14.3	12.2	21.3	18.2	45.6
maximum	29.0	21.0	27.0	36.0	67
Survival, %	50.0	83.3	20.0	15.8	4.2

Table 2. Main growth and survival indices of *Ceratoides papposa* plants in plantings.

Number of specimen Besides cultivation annual and perennial grasses separately, experimental works on formation of pastoral community from two species of plants annual grass - *Salsola nitraria* and a perennial grass - *Alhagie pseudalhagie* (Photo 3) have been made. The height of plants *Alhagi pseudalhagi* at the end of vegetative period is on the site with watering (Photo 3a) – 50,6 cm (average), 73 cm (max) and 25 cm (min), and on the site without watering (Photo 3b) – 43,5 cm (average), 80 cm (max) and 20 cm (min). On the site with watering on 18 models areas 5x5м^2 was fixed in average on 25 specimen *Alhagi pseudalhagi*; the minimal quantity to rich 12 specimen, and maximal – 51 specimen. The height of plants *Salsola nitraria* at the end of vegetative period (the end of September, 2006) is on the site with watering – 52,1 cm (average), 83 cm (max) and 21 cm (min), and on the site without watering– 49,8 cm (average), 81 cm (max) and 25 cm (min).

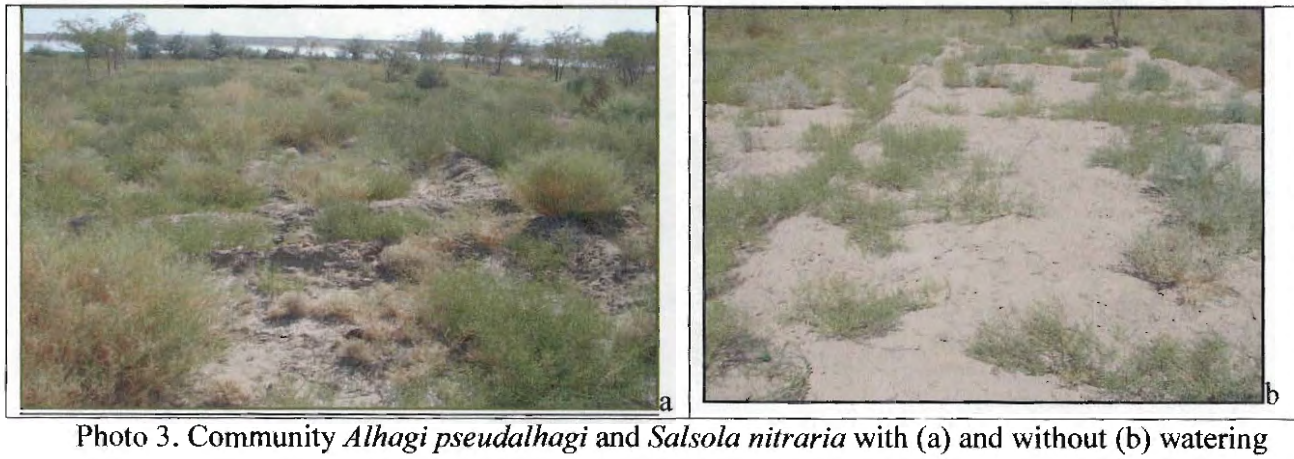

Photo 3. Community *Alhagi pseudalhagi* and *Salsola nitraria* with (a) and without (b) watering

On the site without watering on 18 models areas 5x5м^2 was fixed in average on 12 specimen *Salsola nitraria*; the minimal quantity to rich 0 specimen, and maximal – 27 copies. The total amount plants *Alhagi pseudalhagi* and *Salsola nitraria* in average on the sites with watering was more in 5 and 7 copies (accordingly) than without watering. At the same time the quantity of two species on the 18 sites with watering was distributed more thickly and evenly than on the 18 sites without watering. For *Alhagi pseudalhagi* and *Salsola nitraria* on 67% sites without watering the quantity of plants are 30 and 15 copies (accordingly). At the same time on the all sites with watering the quantity of copies *Alhagi pseudalhagi* and *Salsola nitraria* was more 20 and 15 copies (accordingly), and on 57% from these sites (with watering) it was higher 30 and 20 copies (accordingly).

The total projective cover in average on the sites with watering was higher (51%) than without watering (27%). At the same time the total projective cover on the 18 sites with watering was distributed more evenly (from 40 to 60%) than on 18 sites without watering (from 7 to 60%). On the 83% sites without watering the total projective cover is less than 35%. At the same time on the all sites with watering the projective cover was not less 40%, and on the 63% sites with watering it was higher 50%.

The analysis of distribution of the measured values of heights of annual plants *Salsola nitraria* (maximal, minimal and average), and also the number of plants specimen and the cover density in communities on 24 sites in the size 5x5м2 has shown, that at watering both the general cover density, and number of plants specimen, tab. 6/1 twice increases. Most essentially at watering and without it values of the maximal and average heights of plants specimen *Salsola nitraria* and *Alhagi pseudalhagi* differ among them selves. At watering average values of heights of these plants for each of 12 sites increase for 12 % and 34 % (accordingly), and maximal - on 18 % and 14 %. Thus distribution of the minimal heights of annual plants on sites in the end of a season at watering and without watering has appeared practically identical. Thus, the height of the minimal copies of plants *Salsola nitraria* has appeared not dependent from watering, that also it was marked by us during five years' observation over plantings of bushes of *Haloxylon aphyllum* and saltwort *(Salsola richteri)*, and also sub shrub a winter fat (*Ceratoides papposa)*. Most likely, the height of the minimal specimen of plants depends on character of seeds as внутри-and the intra-specific competition in plantings *Haloxylon aphyllum*, saltwort and a winter fat was completely excluded by technology of plantings (Kouzmina, etc., 2005; 2006).

The same time only at watering are established authentic significant (a=0.05) negative correlation coefficients of average height of plants *Alhagi pseudalhagi* (r =-0.8) and *Salsola nitraria* (r =-0.6) with number of specimen of corresponding plants on 12 modeling sites. Thus at watering, the a lot of plants marked on a site, the below they on the average appeared on height and on the contrary, the less plants grew on a site, the above there was their height, that completely speaks presence of an intra-specific competition for soil moisture. On sites without watering authentic significant correlation it is not revealed.

At creation on the salted grounds mixed pasture with the perennial and annual species close on a habit, it is necessary to consider, that perennial grasses are most competitive in comparison with - annual plants, more considerably increasing the sizes at watering (on 34 %) in comparison with annual plants (on 12 %). Besides it on all sites the number of plants of perennial species *Alhagi pseudalhagi* everywhere was more, than annual plant *Salsola nitraria*: with watering more than 20 specimen (and up to 51), and without watering - more than 12 (up to 51). While for annual plant

Salsola nitraria the number of species did not exceed 30: at watering was from 15 up to 31, and without watering from 0 up to 27.

c) Results of experimental landings of bushes

On experimental site in Muynak area wood and bushes species of plants (*Haloxylon aphyllum* and *Salsola richteri*), begun in March early vegetation, partially freeze. Repeatedly leaves could give not all specimens of plants. Because of it at *Haloxylon aphyllum* in new plantings (2006 and 2007) the percent of losses - up to 90% has considerably increased. On adult (4-years) specimens of plants *Salsola richteri* and *Haloxylon aphyllum*, planted in December, 2005, frosts and a drought have not affected. Adult plants *Haloxylon aphyllum* and *Salsola richteri* have not begun early vegetation. And their powerful root system allows them to reach depth of the ground waters lying below 5.5 m.

The height, adaptability, and survival of *Haloxylon aphyllum* from December 2005 through September 2008 were higher with irrigation (Table 3). Height (among, max., min.) specimen plants *Haloxylon aphyllum* on site with watering in all periods of observations is higher, than on site without watering (Table 3). The survival of plants *Haloxylon aphyllum* in all periods of observations (04.2005, 11.2005, 05.2006; 09.2007) is higher on site with watering (42.7%, 97.9%, 95.7%, 93.6%, 92.6% и 92.6%, on comparison with control (39.0%, 71.9%, 62.5%, 39.1%,32.8% и 29.7%; Table. 3).

Index	Live plants							
Month, Year	*05.04*	*11.04*	*04.05*	*11.05*	*05.06*	*09.06*	*05.08*	*09.08*
Years after plandings	1.5	2.0	2.5	3.0	3.5	4.0	5.5	6
Age, years	2.5	3	3.5	4	4.5	5	6.5	7
Without watering (control)								
Height, cm								
minimum	9.0	8.0	10.0	19.0	15.0	28.0	58.0	18.0*
average	17.3	32.4	25.6	37.3	40.7	81.3	145.5	173.8
maximum	26.0	65.0	45.0	72.0	79.0	156.0	230.0	235.0
Adaptability* and survival, %	39.0*	75.0	68.8	59.4	54.7	54.7	48.0	48.0
With watering								
Height, cm								
minimum	7.0	11.0	10.0	15.0	17.0	23.0	51.0	57.0
average	17.3	35.5	30.0	55.7	63.6	108.6	155.1	183.3
maximum	32.0	65.0	62.0	120.0	121.0	186.0	255.0	265.0
Adaptability* and survival, %	42.7*	97.9	95.7	93.6	92.6	92.6	92.6	92.6

18.0* - Is broken down by a wind.

Table 3. Main growth, adaptability, and survival of *Haloxylon aphyllum* plants in plantings.

Despite the fact that a the end of the first 6 months after planting seedlings, the height of the *Salsola richteri* was greater on the un-irrigated plot; starting from the second 6 months after planting it was higher on the irrigated plot (Table 4), as was plant survival. After ending irrigation, the *Haloxylon aphyllum* under natural conditions on solonchaks felt better than *Salsola richteri*, since they endured more easily the moisture deficit from a reduction of precipitation. They also had a

greater height gain at an age of 2.5- years on plots both with initial irrigation and under natural conditions (Table 4). Four-year observations of the distribution of the minimum heights of the shrubs as well as the semi shrub showed that they depend not on irrigation but only on the quality of the seedlings, since intra- and interspecific competition in the *Haloxylon aphyllum*, *Salsola richteri*, and *Ceratoides papposa* plantings was completely eliminated by the technology of the plantings.

Index	Live plants							
Month, Year	*05.04*	*11.04*	*04.05*	*11.05*	*05.06*	*09.06*	*05.08*	*09.08*
Years after plandings	1.5	2.0	2.5	3.0	3.5	4.0	5.5	6
Age, years	2.5	3	3.5	4	4.5	5	6.5	7
Without watering (control)								
Height, cm								
minimum	14.0	18.0	15.0	19.0	18.0	16.0	24.0	25.0
average	21.8	35.9	30.5	31.1	34.0	57.5	61.3	73.3
maximum	40.0	52.0	45.0	51.0	62.0	99.0	146.0	120.0
Adaptability* and survival, %	39.0*	71.9	62.5	39.1	32.8	29.7	27.0	27.0
With watering								
Height, cm								
minimum	8.0	3.0	8.0	19.0	17.0	16.6	36.0	23.0
average	16.8	38.5	34.8	42.3	44.6	62.3	91.3	87.7
maximum	35.0	70.0	75.0	76.0	98.0	151.0	150.0	161.0
Adaptability* and survival, %	32.3	87.5	84.4	84.4	84.4	82.8	80.2	80.2

Table 4. Main growth, adaptability, and survival of *Salsola richteri* plants in plantings

To monitor the development of the transplanted shrubs on solonchaks of the desiccated sea bed, they were compared with seeded *Haloxylon aphyllum* plants on plots of non-saline soils. Annual double irrigation with fresh waters and single weeding were carried out on one part of the non-saline plot; on another part, in addition to double irrigation fertilizers were applied annually and weeding was done twice; the third part of the plot was the control, though late (summer) weeding was done without irrigation and fertilizers. During the first two years the plantings were irrigated along furrows in March and June as well as in May and June. Thus, the plots being compared-solonchaks and non-saline soils-had even-aged 2-year-old *Haloxylon aphyllum* plants. They were set out as year-old seedlings on solonchaks; on non-saline soils they were initially grown from seeds placed in furrows-ridges plowed prior to this, spaced 1 m apart.

The average, maximum, and minimum heights of the plants on the un-irrigated plots at an age of 2-3 years differed insignificantly: for 2-year-old plantings, 32.4, 65, and 8 cm (on solonchaks) and 34.3, 82.9, and 9 cm (on non-saline soils); for 3-year-old plantings, 37.3, 72, 19 cm and 46.6, 88, and 22 cm. At the same time, on solonchaks with irrigation with saline water, the plant height indices were even higher than in the control on non-saline soil: for 2-year-old plantings, 35.5, 65, and 11 cm; for 3-year-old plantings, 55.7, 120, and 15 cm. But already at an age of 3.5 years they differed substantially without irrigation on saline and non-saline soils: 40.7, 79, and 15 cm and 1.2.3, 166, and 25 cm. In this case, under conditions of irrigation with non-saline water on non-saline soils (up to 0.3

%), the height indices of plants aged 2 and 3 years were considerably higher, respectively 44.9, 81, and 11 cm and 126.1, 148, and 105 cm. The best plant growth results were achieved during 2 years with double freshwater irrigation and single fertilization annually: 126.6, 190, and 70 cm. However, owing to intraspecific competition with such type of growing, during each 6 months the number of *Haloxylon aphyllum* in each of the ridges on no saline soils decreased by 53-57% of those that had originally grown, hi this case, adaptability on no saline soils remained considerably higher (by 20-40%) than on solonchaks on the desiccated sea bed.

III.2. Biomass production, seed yields and tissue osmolarity of *Salicornia bigelovii* in relation to irrigation salinity

Introduction

Liquid biofuels can theoretically replace or supplement petroleum fuel supplies, reducing the U.S. dependence on foreign oil, and reducing net carbon dioxide emissions by replacing fossil fuels with renewable sources. However, a drawback to conventional biofuel crops is that they require the diversion of farmland, pastures, and rangelands from food to fuel production. A promising avenue is the production of biofuels from halophyte crops (Glenn et al., 1999; Hendrick and Bushnell, 2008; Rozema and Flowers, 2009), as they can be produced on land that is not suitable for conventional agriculture.

A major candiate for development as a biofuel crop is *Salicornia bigelovii*, a saltmarsh plant that produces substantial yields of oil seeds and has been produced in commercial settings (Glenn et al., 1991, 1998). In this report we examine the biomass production and seed yield of two lines of *Salicornia bigelovii* in response to irrigation salinity.

Materials and Methods

The research was carried out at the Environmental Research Laboratory (ERL) of the University of Arizona. Plants of two *S. bigelovii* lines, one from Texas and one from Florida, were grown in a greenhouse in 1-gallon pots filled with a mixture of sand and potting soil (Fig. 5). Seeds were obtained from the ERL seed collection and germinated in nursery trays under freshwater irrigation. When the plants were approximately 1 cm in Height they were transplanted to the 1-gallon pots. The plants were subsequently irrigated with saline water at either 5, 15, or 30 ppt. Salinities of the irrigation water were achieved through the use of commercially available salts for artificial seawater (Marine Enterprises International) Commercial fertilizer (Miracle Gro™)was added at 0.165 g/l. Each pot was irrigated with 0.5 gallons/hour three times per day via a drip irrigation system with pumps and timers. The experiment lasted 120 day, at which time most of the plants had begun to senesce.

After harvest, the plants were placed individually in paper bags and air dried. The dry mass of each plant was determined by weighing them on an electronic balance. Seeds were obtained following methods in Glenn *et al.* (1991). Dry plants were milled in a harmer mill and the chaff screened on a series of agricultural screens. For each plant, one gram of the seed and remaining chaff was weighed and the seeds counted by hand. This was used to determine the number of seeds produced per plant. Then, for each plant, groups of twenty seeds were weighed with an analytical balance. This allowed calculation of the seed mass, both individually and collectively per plant, in grams.

Figure 5. Arrangement of *Salicornia bigelovii* plants in growth trials in a greenhouse at the Environmental Research Laboratory of the University of Arizona.

Results and Discussion

There were no significant differences in mean final biomass of plants among lines or among irrigation salinities (Table 5, Fig. 6) and final values ranged from 183 to 228g. Based on the size of the crop canopy, the total biomass production was approximately 12,000 kg/Ha.

Source	DF	SS	MS	F	P
sal	2	5716	2858.11	0.73	0.4869
var	1	423	422.98	0.11	0.7437
sal*var	2	8726	4362.76	1.11	0.3362
Error	49	191774	3913.76		
Total	54				

Table 5. Analysis of Variance results for final dry mass (g) of *Salicornia biglovii* plants in growth trials. Sal=salinity, var=variety.

The mean dry mass both of individual seeds among salinities differed among both salinities and plant lines with a signicant interaction between these variables (Table 6). The maximum seed individual weight was found at the treatment 15ppt in the Texas line with a value of 1.5 $x10_{-2}$ g and the minimum seed individual weight was found at 5ppt irrigation salinity in the Texas line with a value of 0.45 $x10_{-2}$ g. For both lines, the highest seed weights were found in the plants irrigated with saline water at 15 ppt, and the effect of salinity on seed weight was more pronounced in the line from Texas (Fig. 7).

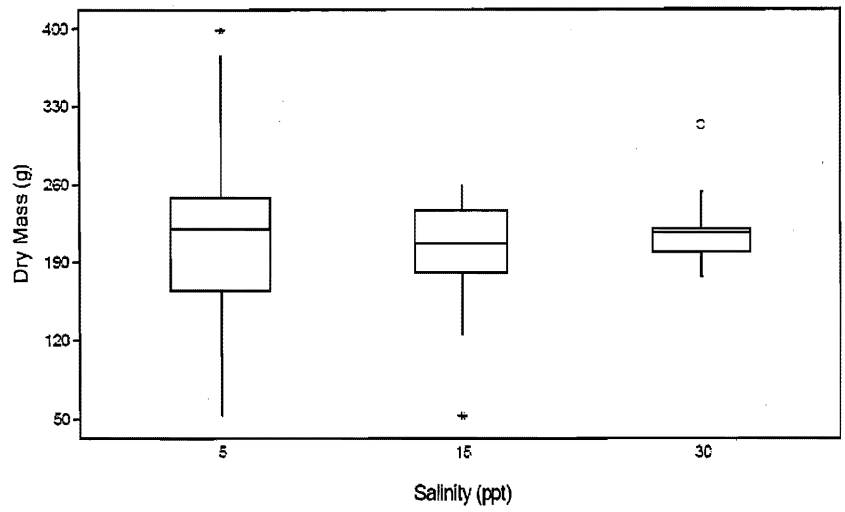

Figure 6. Final dry mass (g) of *Salicornia bigelovii* plants grown in 1-gallon pots with irrigation salinities of 5, 15, or 30 ppt.

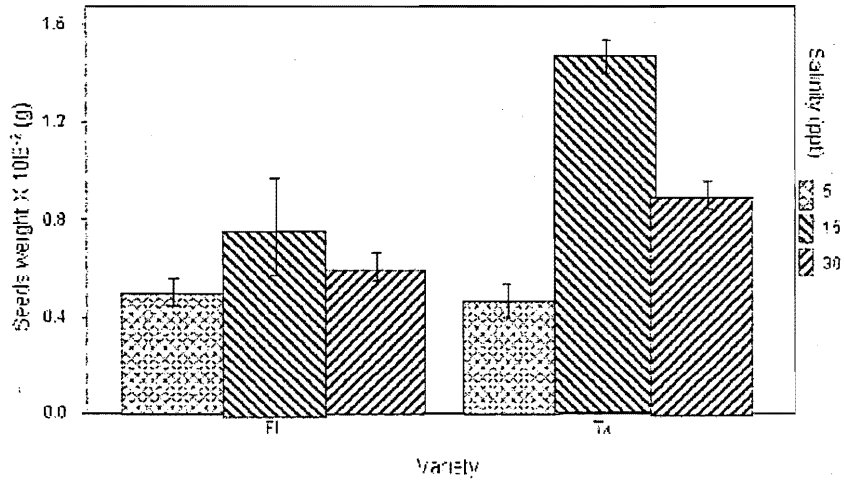

Figure 7. Mean dry mass (g) of individual seeds from two varieties of *Salicornia bigelovii* plants grown in pots irrigated with saline water at either 5, 15, or 30 ppt

The total seed yields (g) per plant were significantly different among irrigation treatments, but not between the *S. bigelovii* lines (Table 7). The maximum seed yields were obtained in the treatments at 15ppt for both Texas and Florida lines with values of 53 g and 28 g respectively. The minimum seed yields were found at the 5ppt treatment in both Texas and Florida lines with values of 13 g and 6 g respectively (Fig. 8). In addition, the color of the seeds differed among treatment groups (Fig. 9).

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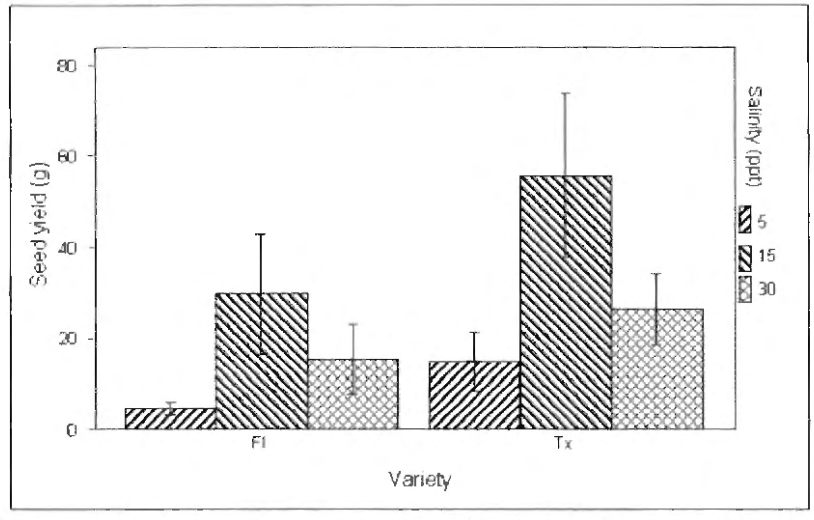


Figure 8. Seed yield (g) per plant in greenhouse trials with two varieties of *Salicornia bigelovii*

The results indicate the halophyte *Salicornia bigelovii* grows well at salinities from 5 to 30 ppt, with the best seed yields produced at intermediate salinities of 15 ppt. Hence, in the United States, this crop is suitable for production on inland waters of a variety of salinities and could become an important source of biofuels, reducing dependence on imported crude oil without negatively affecting conventional crop production.

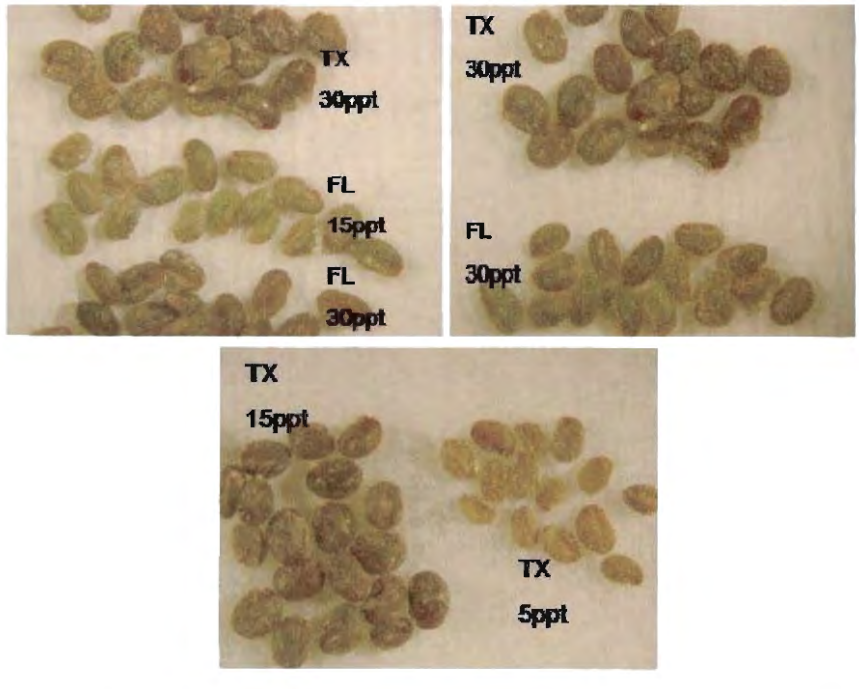


Figure 9. The color and size of seed *Salicornia bigelovii* varied in response to irrigation salinity

III.3. Effect of temperature and salinity on seed germination in *Salicornia europaea* L. from Central Asia

Introduction

Salicornia europaea L. (Chenopodiaceae), is an annual halophyte species widely distributed on wet solonchaks in Turkmenistan. Its distribution range extends from seashore of Kaspian sea on West to Kugitangtau mountain range on East, and flood-lands of Amudarya river (Kurbanov, 2005). Kurbanov (2005) indicated that biomass of *S. europea* vegetation in Turkmenistan is ~ 1.1 ton per hectare covering a total area of two million hectare. However, in spite of its abundance, *S. europea* plants are not used for food, pharmacology or any other practical use. The bio-ecological properties of *S. europea* (Turkmenistan ecotype) including the biology of germination are not known.

Temperature and soil salinity are among the major environmental effects on seed germination. During germination these two factors are interacting (Ungar, 1978; Badger and Ungar, 1989; Khan and Ungar, 1996; Khan, 1999; Khan and Gul, 2006) with plant responses being species-specific. In some species low temperature inhibits germination. For example, germination percentage of *Kochia scoparia* was improving with temperature, reaching maximum at 25°- 35°C (Khan, Gul and Weber, 2001). Other species best germinate at intermediate (*Zygophyllum simplex*) or low temperatures (*Cressa cretica, Atriplex griffithii*) (Khan, 1999). Usually, both factors high temperature and low osmotic potential cause inhibition and reduction of germination, and have a synergetic effect (Ungar, 1978). Khan and Gul (2006) reviewed combined effects of temperature and salinity on germination of halophytes originating from different climatic regions. They found that increase in temperature improves germination in species from cold deserts, while the opposite is true for the species from hot deserts and temperate regions. The highest germination percentage of *S. europaea* according to these authors was under alternating temperatures 5 - 25°C. Lower germination was recorded under both decrease (10-20°C и 5-15°C) and increase in temperature (20-30°C). On the other hand, in a study of Ungar (1967) the optimal temperature for germination of *S. europaea* was 32°C under all tested salinity concentrations (0.5-5% NaCl). Ungar (1977) also showed that increasing salinity inhibits seed germination in this species at all tested temperatures (from 10 to 30°C).

Effect of temperature is important in germination recovery of halophytes being exposed to salt stress, and this effect may be species-specific (Khan and Ungar, 1977). Experiments in *S. europaea* indicated high germination percentages and rate of recovery following 2-yr exposure to hypersaline conditions (Keiffer and Ungar, 1997). Despite of existing literature data the combined interaction of temperature and salinity impact as well as recovery germination effect are still not enough studied. Therefore, in the present study the germination behavior of *S. europaea* from Turkmenistan (Central Asia) was 1) examined under constant and alternating temperatures and different salinity in laboratory conditions; 2) compared with published results obtained for *S. europaea* originating from other climatic regions.

Materials and methods

Seeds of *S. europaea* were collected from natural populations in desert area of Turkmenistan (Central Asia) in October-November 2004 and stored in paper bags in a refrigerator (+4°C). Experiments started in May 2007, after storage for 2.5 years. In each treatment, fifty seeds placed on Whatman filter papers in 50 mm diameter Petri dishes received 7 ml of test solution. There

were 7 regimes of constant (5°, 10° 15°, 20°, 25°, 30° and 35°C) and 6 regimes of alternating (5°-20°, 5°-25°, 5°-30°C and 10°-20°, 10°-25°, 10-30°C) temperatures. Salinity treatments included distilled water (control), 1%, 2%, 3%, 4%, 5% and 7% NaCl in the case of constant temperatures, and control, 1%, 3%, 5% and 7% NaCl in the case of alternating temperatures in dark. There were for replicates per treatment. The results of germination were recorded every day for 2 month.

Non-germinated seeds from high salinity treatments were transferred to distilled water to study the recovery of germination. For determination of the recovery percentages we used an equation $(b-a)/(c-b)*100$, where a is total number of seed germination after being transferred to distilled water, b is the total number of seed germination in saline solution, and c is a total number of seeds.

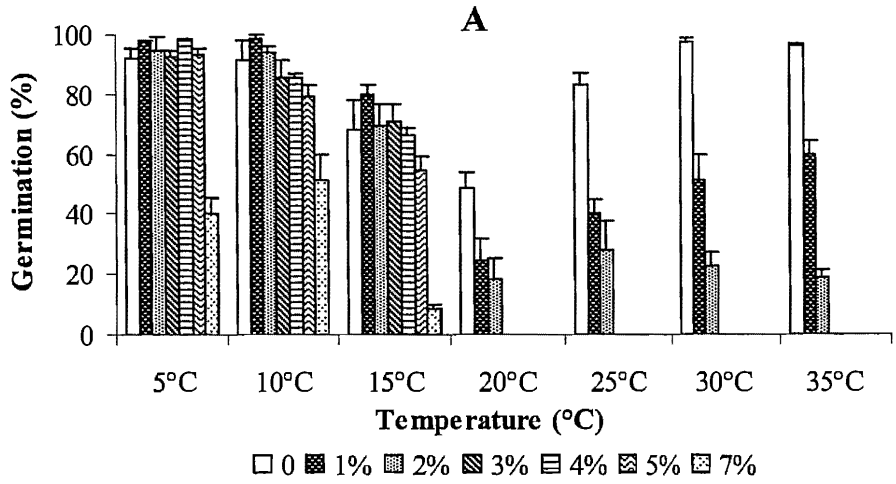
For calculation of the rate of germination we used the modified Timson index of germination velocity = JG/t (Khan and Ungar, 1984), where G is the percentage of seed germination at 2-days intervals and t is the total germination period.

All data analyses were performed using SPSS version 13.0 (SPSS, Inc., Chicago IL).

Results

The final germination percentage of *S. europaea* seeds in distilled water ranged from medium to high under constant temperatures (Fig. 10A). High germination value was observed under low (5° and 10°C) and high (30° and 35°C) constant temperature regimes. The moderate seed germination of about 43% was marked at 20°C treatments. Under temperature above 20°C seeds did not germinate when subjected to salinity from 3 to 7% NaCl. Under low temperature (5° and 10°C) seeds germinated from 1 to 5% NaCl salinity concentrations, and seed germination value were similar to or higher as control. The temperature treatment showed a significant impact on period of seed germination, i.e. under high permanent temperatures seed germinated quickly during two weeks, while under low permanent temperatures seed germination rate was delay up two months. Additionally seed germination rate was greatly retarded with increasing salt salinity concentration under all temperature regimes (Fig. 11-12).

The effects of alternating and constant temperature regimes were similar. When exposed to high salinity, seeds did not germinate under high alternating temperature regimes, but did germinate under low temperature regimes 10/20°C and 5/20°C. Under these regimes tolerance limit was 7% and 5% NaCl, respectively. There were some differences between effects of the two temperature regimes. The final germination percentages in distilled water under alternating regime were gradually decreasing with decrease in temperature, and time to germination was significantly shorter than under constant temperatures.



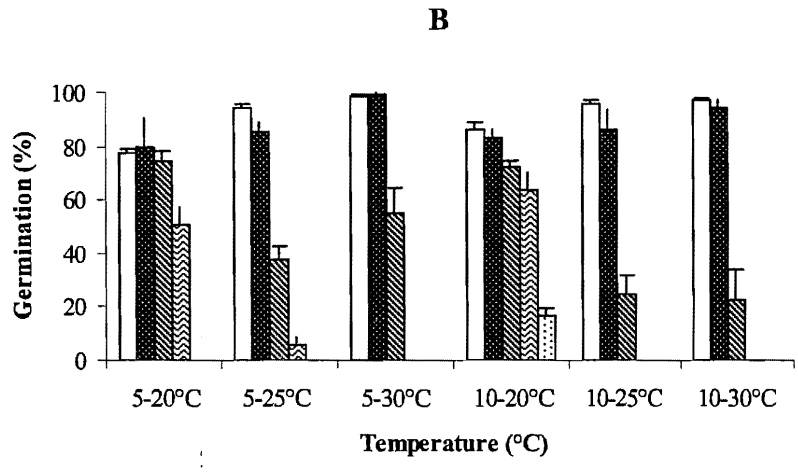


Figure 10. Final germination percentages for seeds of *Salicornia. europaea* germinated at constant (A) and alternating (B) temperature regimes in different salinity NaCl (%).

Germination rate under both constant and alternating temperature regimes positively correlated with temperature (Table 7 and 8). Two-way ANOVA showed the temperature, salinity and their interaction significantly affected on seed germination and rate germination of both constant and alternating temperature regimes ($p < 0.0001$).

In general, the average values of germination recovery for both temperature regimes were high (Table 9 and 10). The maximum germination recovery was detected under 30°C and 10/30°C. Differences between these two temperature regimes (permanent and alternating) were reflected in the oscillation of seed recovery germination (Fig.13). Under constant temperature the two-way ANOVA revealed no effect of salt concentration ($p < 0.582$), substantial effect of temperature ($p <$

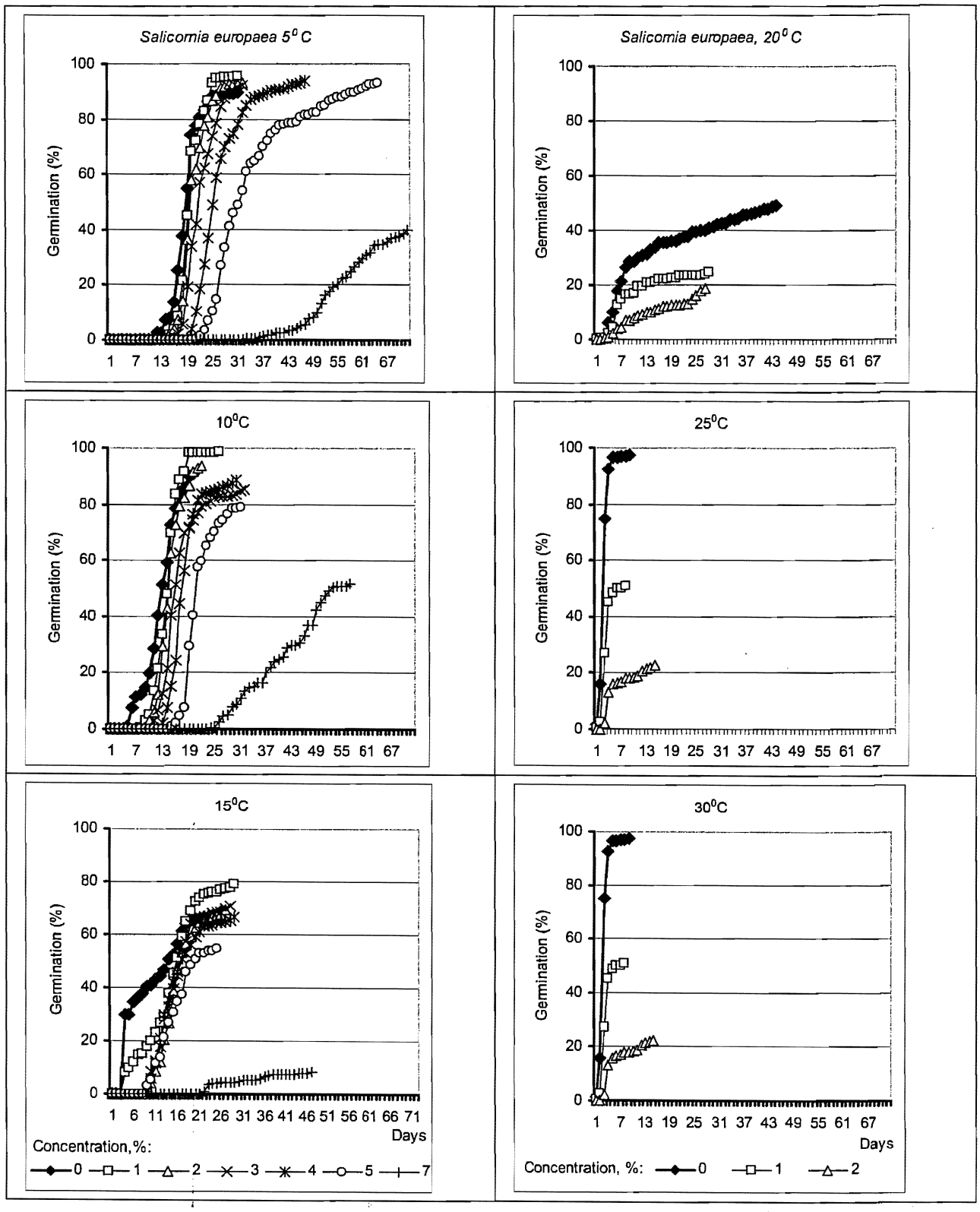


Figure 11. Mean germination percentage depending on time of *Salicornia europaea* in different salinity NaCl (%) at constant thermo periods.

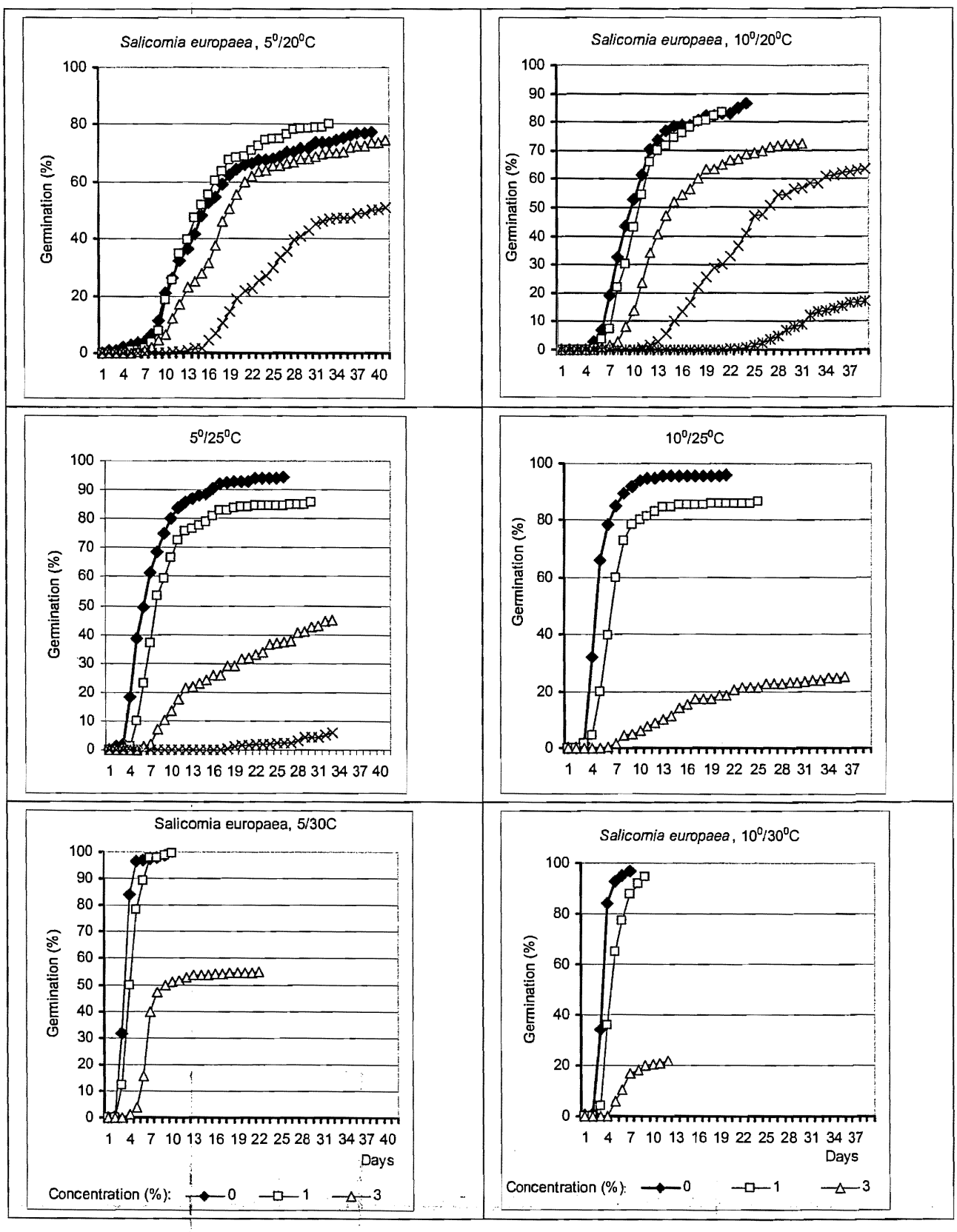


Figure 12. Mean germination percentage depending on time of *Salicornia. europaea* in different salinity NaCl (%) at alternating thermo periods.

0.002), and weak effect of their interaction ($p < 0.076$) on recovery germination. However, under alternating temperature regimes all three effects were significant ($p < 0.0001$) for both germination rate and recovery (Table 11 and 12). Under constant temperature regimes the rate of germination recovery was weakly affected by salt concentration ($p < 0.01$), but highly depended on temperature and synergetic effect of temperature and salinity ($p < 0.0001$). The rate of germination recovery was maximal under high temperature in both constant and alternating regimes.

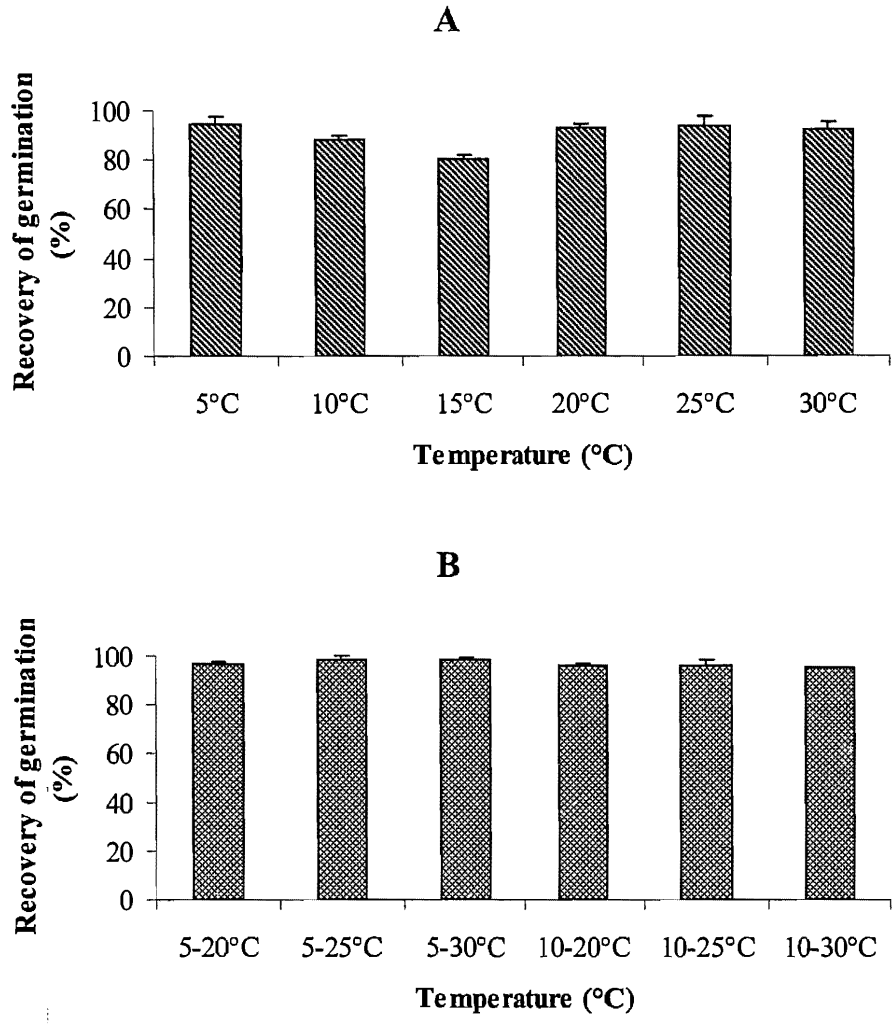


Figure 13. Percentage recovery of germination of S. europaea at different constant (A) and alternating (B) temperature regimes after long time exposed in 7% NaCl.

Discussion

Khan and Gul (2006), analyzing effects of temperature and salinity on seed germination of halophytes from different ecological regions, classified *S. europaea* as a species from moist temperate regions. The authors considered halophytes from this region best germinating under alternating temperature regime 5-15°C. Philipupillai and Ungar (1984) reported positive effect of cold pretreatment on salt tolerance in *S. europaea* (up to 5% NaCl vs. 3% NaCl without pretreatment). These experiments also showed that germination percentage was higher under low alternating regimes (5-15°C and 5-25°C). Salt tolerance of halophytes depends on temperature.

Seeds of *Aeluropus lagopoides* were germinating under salinity up to 500 mMol NaCl when alternating temperature regime of 20°:30°C was applied and were not germinating with 10°:20°C. Salt tolerance of *Halopyrum mucronatum* was 400 mMol NaCl under 15°:25°C and 20°:30°C and decreased to 200-300 mMol under 10°:20°C and 25°:35°C (Badger and Ungar, 1989). *Salicornia bigelovii* seeds readily germinated under concentrations of NaCl from 0 to 8% when temperature was 4.4°C, but had high germination percentage only under low concentrations of NaCl when temperature was 26.6°C (Rivers and Weber, 1971). A typical halophyte shrub, *Halocnemum strobilaceum*, often growing together with *S. europaea*, has salt tolerance limit of 0.5 M (corresponding to approximately 3% NaCl) and has a good germination under high temperature (Qu et al., 2007).

Our results confirmed positive effect of low temperature on germination of *S. europaea* seeds. The highest germination percentage, as well as increase in tolerance limits to 7% NaCl was detected under low constant and alternating temperature regimes. On the other hand, high temperatures inhibited germination and decreased tolerance limits under constant temperature regime to 2% NaCl and under alternating regime to 3% NaCl.

No doubt those alternating temperature regimes are closer to natural conditions than constant ones. However, the constant regime better indicates high species plasticity in its response to temperature. Under this regime maximum germination was observed in a wide range of temperatures (from 5 to 15°C) and salinity (from 1 to 5% NaCl). Among experimented alternating temperature regimes the maximum seed germination was observed at 10/20°C at all salt concentration level even at 7% NaCl. It was suggested by Ungar (1978) that inhibition of germination under high temperature is caused by temperature effect on enzymatic activity. It seems that in *S. europaea* enzymes are activated by low and inhibited by high temperatures. However, seeds of *S. europaea* showed the lowest germination speed under low temperatures and germination under low temperatures lasted for two and more months.

There is a relationship between temperature and recovery of seed germination (Khan and Ungar, 1997). In *Haloxylon recurvum*, *Suaeda fruticosa*, *Zygophyllum simplex* and *Triglochin maritima* percentage of non-germinated seeds that recovered after transfer to distillate water varied significantly with temperature (Khan and Ungar, 1997). Our results show germination recovery in all temperature regimes, but the highest percentage and rate recovery were under constant 30°C and alternating 5-30°C и 10-30°C. After keeping seeds in 7% NaCl for one month (seeds did not germinate) final percentage of germination recovery varied under constant temperature regimes between 80.3% and 94.5%, and under alternating regimes 95.5-98.5%. Although germination recovery was high in all treatments, alternating temperature regimes were more effective than constant ones.

Seeds of *S. europaea* from Turkmenistan, after storage for 2.5 years in a refrigerator, retained good germination ability. Their ability to germinate under certain degree of NaCl salinity was temperature-dependent. Highly salt-tolerant species, *S. europaea* is very plastic in seed response to environmental conditions, which insures germination in spring under both low and high temperature in rapidly changing climate conditions of arid regions.

Table 7. Rate of seed germination of *Salicornia europaea* at constant temperature

Concen-tration (%)	Temperature						
	5°C	10°C	15°C	20°C	25°C	30°C	35°C
0	2.28 ± 0.17	4.58 ± 0.6	2.64 ± 0.7	1.11 ± 0.21	1.80 ± 0.16	9.75 ± 0.19	9.6 ± 0.16
1	3.05 ± 0.03	3.81 ± 0.07	2.36 ± 0.5	0.89 ± 0.5	1.67 ± 0.39	6.37 ± 2.14	3.72 ± 0.44
2	2.97 ± 0.27	4.27 ± 0.19	2.48 ± 0.5	0.66 ± 0.48	1.07 ± 0.76	1.40 ± 0.59	1.05 ± 0.26
3	2.91 ± 0.11	2.67 ± 0.36	2.52 ± 0.4	0	0	0	0
4	2.04 ± 0.03	2.95 ± 0.1	2.22 ± 0.1	0	0	0	0
5	1.42 ± 0.07	2.47 ± 0.27	2.09 ± 0.3	0	0	0	0
7	0.56 ± 0.16	0.89 ± 0.28	0.17 ± 0.06	0	0	0	0
Results of two-way ANOVA							
Variable	Concentration of salinity (C)		Temperature (T)		Interaction C*T		
Rate germination	2.5435E -85		6.3187E-60		6.3055E -71		

Table 8. Rate of seed germination of *Salicornia europaea* at alternating temperature

Concen-tration (%)	Temperature					
	5°C~20°C	5°C~25°C	5°C~30°C	10°C~20°C	10°C~25°C	10°C~30°C
0	2.02 ± 0.1	3.63 ± 0.07	9.85 ± 0.1	3.60 ± 0.2	4.36 ± 0.07	12.13 ± 0.3
1	2.35 ± 0.1	2.84 ± 0.2	9.25 ± 0.1	3.79 ± 0.3	3.33 ± 0.5	9.45 ± 0.6
3	1.86 ± 0.2	1.32 ± 0.3	2.5 ± 0.8	2.26 ± 0.2	0.69 ± 0.3	0.94 ± 0.9
5	1.27 ± 0.3	0.18 ± 0.2	0	1.58 ± 0.4	0	0
7	0	0	0	0.43 ± 0.1	0	0
Results of two-way ANOVA						
Variable	Concentration of salinity (C)		Temperature (T)		Interaction C*T	
Rate germination	1.4435E -83		8.9656E -59		1.4894E -63	

Table 9. Recovery germination of *Salicornia europaea* at constant temperature after exposed in 3, 4, 5 and 7%NaCl and results of two-way ANOVA

Concen-tration (%)	Temperature					
	5°C	10°C	15°C	20°C	25°C	30°C
3		70.3 ±17.2	82.5 ± 17.2	98.5 ± 3.0	96.0 ± 2.8	96.0 ± 3.3
4		91.9 ± 9.7	86.8 ± 9.7	97.0 ± 3.5	89.5 ± 5.5	97.5 ± 1.9
5		90.0 ± 8.8	89.8 ± 8.8	85.0 ± 8.9	91.0 ± 6.8	98.0 ± 1.6
7	94.5 ± 7.1	87.8 ± 2.7	80.3 ± 2.7	93.0 ± 2.6	94.0 ± 7.1	92.0 ± 5.9
Results of two-way ANOVA						
Variable	Concentration of salinity (C)		Temperature (T)		Interaction C*T	
Percent recovery	0.58201		0.00232		0.07605	

Table 10. Recovery germination of *Salicornia europaea* at alternating temperature after exposed in 3, 5 and 7%NaCl and results of two-way ANOVA

Concen-tration (%)	Temperature					
	5°C~20°C	5°C~25°C	5°C~30°C	10°C~20°C	10°C~25°C	10°C~30°C
3	64.0 ± 24.1	52.5 ± 15.0	55.0 ± 2.3	41.7 ± 19.3	69.5 ± 16.1	98.9 ± 1.3
5	95.2 ± 3.5	93.5 ± 5.3	97.0 ± 2.6	78.2 ± 16.9	96.5 ± 3.0	95.5 ± 2.5
7	96.5 ± 1.9	98.0 ± 2.3	98.5 ± 1.0	96.4 ± 1.3	96.0 ± 5.4	95.0 ± 1.2
Results of two-way ANOVA						
Variable	Concentration of salinity (C)		Temperature (T)		Interaction C*T	
Percent recovery	6.471E-15		0.00012		0.00030	

Table 11. Rate of recovery germination of *Salicornia europaea* at constant temperature after exposed in 3, 4, 5 and 7%NaCl and results of two-way ANOVA

Concen-tration (%)	Temperature					
	5°C	10°C	15°C	20°C	25°C	30°C
3		0.61 ± 0.2	2.04 ± 0.7	4.19 ± 0.3	48.0 ± 1.4	42.0 ± 12.1
4		1.19 ±0.4	2.36 ± 0.6	5.53 ± 1.4	14.28 ± 5.4	42.6 ± 12.1
5		2.22 ±0.5	5.42 ± 0.4	8.33 ± 1.9	22.4 ± 18.0	49.0 ± 0.8
7	16.8 ± 9.3	15.4 ±14.4	6.67 ± 1.6	17.96 ± 5.6	13.08 ± 3.0	46.0 ± 2.9
Results of two-way ANOVA						
Variable	Concentration of salinity (C)		Temperature (T)		Interaction C*T	
Rate recovery	0.01185		2.0148E-26		9.2791E-08	

Table 12. Rate of recovery germination of *Salicornia europaea* at alternating temperature after exposed in 3, 5 and 7%NaCl and results of two-way ANOVA

Concen-tration (%)	Temperature					
	5°C~20°C	5°C~25°C	5°C~30°C	10°C~20°C	10°C~25°C	10°C~30°C
3	4.79 ± 3.5	23.67 ± 1.1	43.2 ± 4.2	2.08 ± 0.3	14.04 ± 2.5	49.43 ± 0.6
5	23.79 ± 0.8	24.87 ± 0.3	48.5 ± 1.3	7.29 ± 3.8	22.04 ± 3.6	23.88 ± 0.6
7	16.08 ± 0.3	24.5 ± 0.5	24.6 ± 0.3	20.0 ± 1.0	12.0 ± 0.6	15.83 ± 0.2
Results of two-way ANOVA						
Variable	Concentration of salinity (C)		Temperature (T)		Interaction C*T	
Rate recovery	1.5512E-14		5.613E-40		1.5223E-33	

IV. Impact, Relevance, and Technology Transfer

The Karakalpakistan and Kyzylorda district of Kazakhstan irrigated areas, the main agricultural regions in the southern part of the Aral Sea coast, represent an area of extreme ecological disaster. As much as 1,367,000 ha of irrigated land in the Aral Sea region, which is 60-65% of the irrigated areas, have undergone secondary salinization. More than 3 million people live there. Reduced crop and fodder productivity as a result of degradation of irrigated lands and the environment, affect significantly the living standards of the local population. The anticipated results of the proposed

research will be of significant practical importance for all Central Asian regions where salinization is occurring. For the first time local and introduced halophyte species will be cultivated intensively in Aral Sea region, in order to improve productivity of degraded, salt-affected and poor soils, as well as for biological sand dune fixation.

Development of halophyte cultivation can add significantly to the irrigated cropland of the world. It may provide over half of the two million square km of new cropland that FAO has estimated would be needed to support an expected doubling of human population in the arid lands. An important environmental benefit of halophyte agriculture is that the use of salty deserts for new cropland will be an alternative to the further clearing of forests and damming of rivers for new irrigated fields.

The main goal of the proposed research was to creation of a halophyte genebank and development of halophyte-based agriculture in the Aral Sea region by irrigation of halophytes with brackish water.

As a result of this project, at the first step the selected halophyte species were evaluated experimentally under brackish and salty water irrigation; at the second step the best performing species were tested in the field on the dry bottom of Aral Sea; and the next tasks of proposed study were development of methods of seed storage, germination, nursery management and propagation of the best performing species and monitoring of halophyte plantations. The results of this research will make it possible to determine the best ways of soil preparation, methods of sowing on sandy and salty soils, seed treatment and seeding rates, the optimal nutritive and irrigation regimes, the experimental ground and principles and different placing in systems of halophyte irrigated agriculture. The results of ridge planting of *Haloxylon aphyllum* and *Salsola richteri* shrubs and *Ceratoides papposa* semishrub on bare solonchaks of the dried-out floor of the Aral Sea with minimum irrigation with waste waters or without it can be considered satisfactory. However, the shrub halophytes achieve best development and adaptability on non saline soil with irrigation with fresh waters. *Haloxylon aphyllum* plantings under natural conditions on solonchaks of the dried Aral Sea bed endure a moisture deficit from a decrease in atmospheric precipitation better than *Salsola richteri* plantings

The innovation of the proposed research comes from its multidisciplinary nature, as a combination of agriculture, reclamation ecology, soil science, management and optimization of land use. For the first time halophytic species will be introduced into irrigated cultivation in Central Asia. This embodies a viable alternative to cultivation of conventional species under intensive irrigation. It brings the potential to utilize brackish water and saline soils, which are available in excess, and to provide vast amounts of fodder for animal husbandry, a key aspect of the agrarian economies of the Aral region.

The research experience will equip the collaborators and their respective institutions with the technology for efficient cultivation of local halophytes on salt-affected soils. The results will enhance their knowledge of dormancy and germination of halophyte species, the potential of halophytic plants for sand dune fixation and as forage for animal husbandry, which will aid them in continuing this direction of research and in developing new research programs.

Young Central Asian researchers were trained in Israel and will strengthen researches capacity of their country upon their return. The participating laboratories of the two collaborating Central Asian countries was provided with necessary modern equipment for the study of soil/water chemistry, including soil moisture sampler set, digital pH meter, multi-purpose water analysis meter, irrigation

test kit, conductivity meter and electronic balance. They were also received various irrigation supplies including drip and sprinkle irrigation equipment for establishment of experimental plots.

During implementation our project we have contacted with different scientists from Karakalpak State University, Bioecological Institute, Complex Institute of Natural Sciences, Institute of Botany and participating in cooperation field survey. We have discussed and worked out new methods and methodology our research with taking into account the specific ecological conditions of the Aral Sea region, that allow as to use in our studying on experimental sites of new halophyte species which has shown good results and can be recommended at creation of halophyte pastures within of Aral Sea region. The outputs our research work will be conductive to sustainable agricultural development in the Aral Sea basin and first of all live-stock-breeding and providing of fodder.

The experimental sites on growing of halophyte species were created on lands which belong of Mo'ynoq forestry (The North part of Karakalpakstan) and local specialists from Mo'ynoq forestry to take part in cooperation scientific investigations. The local specialists has been learned the methods on create artificial pastures with use of halophyte species. We also are participating in cooperation field survey in the immediate on sites of Muynak forestry. On this sites we selecting soils and ground waters samplings, description of vegetation and gives our recommendations on organization of scientific survey and monitoring on this sites.

V. Project Activity/Outputs

Travel:

Prof. O. Ashirmetov (Uzbekistan) and Dr. M. Vilgelm (Kazakhstan) were in Israel in February 15-22, 2006. They detailed discussion of methodology and plans for the future work. In addition, they visited the Institute for Applied Research of Ben-Gurion University, Botanical Garden of Jerusalem and Regional Council Central Arava where they have acquainted with methods of prevention of desertification processes in Israel.

Prof. N. Orlovsky and Dr. S. Volis (both from Israel), Dr. Treshkin and Dr. Kouzmina (both from Uzbekistan) visited Kyzylorda, Kazakhstan during October 17-26, 2006 for the kick-off meeting with Kazakhstan partners from the Priaral Research Institute of Agroecology of the Ministry of Science of Republic Kazakhstan. They planned the activities of the project and visited of the future research site on the dry bottom of Aral Sea.

Prof. N. Orlovsky and Dr. S. Volis (Israel) were in Kyzylorda, Kazakhstan during October 11-22, 2007. They visited the experimental site in the dry bottom of Aral Sea. In addition, together with Kazakh participants of the project, they visited the field station of the Priaral Research Institute of Agroecology of the Ministry of Science of Republic Kazakhstan where research ways of improvement of desert ranges. The time together was spent most profitably also for evsluating progress in the program and plans for the future work.

Training:

Mrs. T. Pak from Uzbekistan and Mr. A. Karlykanov from Kazakhstan have being staying in Israel for training in period from February to August 2006. The purpose of the training was to determine the effect of various salt and their concentration on the seeds germination of different halophytic species. The chloride, sulfate and carbonate with concentration of 0.5, 1, 2, 3 and 5% were used in the experiments.

Mrs. U. Japakova from Uzbekistan (from February to August 2007), Mr. Y. Jamantikov (from

May to October 2008) and Mrs. I. Shulgina (May –December 2007, January-May 2008, both from Kazakhstan) visited in Israel for training. Young scientists from target countries were trained in methods of plants propagation, statistical analyses and agro-management in Israel. In the framework of their training they visited to Arava Valley to the Hatzeva Agricultural research and Development Center, and moshav Pharan for familiarization with greenhouse agricultural practices under extremely arid conditions.

Publications:

1. Djamantikov, Kh., Vilgelm, M, and Djamantikov, E. 2007. Biological melioration of soils of dry bottom of Aral Sea. *AgroInform,* No 8 (62): 22-23 (in Russian)
2. Orlovsky, N., Japakova, U., Volis, S., and Shulgina, I. Comparative study of seed germination and growth of *Kochia prostrate* and *Kochia scoparia* under salinity. *Journal of Arid Environments* (Submitted)
3. Japakova, U., Orlovsky, N., Gendler, T., and Volis, S. Effect of temperature and salinity on seed germination in *Salicornia europaea* from Central Asia. *Arid Ecosystems* (Submitted)
4. Orlovsky, N., Japakova,U., Zhang, H., and Volis, S. Effect of salinity on seed germination, growth and ion content in dimorphic seeds of *Salicornia europaea. Weed Reasearch* (Submitted)

VI. Project Productivity

All project goals were achieved. The new experimental methods on planting and seedling of halophyte species on the dried Aral Sea bottom have been development. These methods can be used in the other Central Asian regions with similar conditions. The halophytic spicies can play a significant role in the agricultural development of salt-affected lend.

By results of the project the scientific program of the further researches " Forest reclamation on the dried bottom of the Aral Sea by seedling and seeds of *Haloxylon* species, increase them survival and survival rate" is made, This program will be carried out of the Priaral Research Institute of Agroecology of the Ministry of Republic Kazakhstan.

VII. Future Work

Although several halophytic species are already used successfully, ours study makes clear that, in many cases, further dissemination of halophyte utilization needs more research and field trials for experimentation and demonstration. Most halophytes grow only wild up to now. The potential to improve their characteristics to be used as a crop is immense and should be exploited by scientists. Field trials need to be analyzed under economic aspects.

In the future it is necessary to study use of halophytic species:

a) For waste and wastewater treatment and fixation of heavy metals.
b) For landscaping as shore protection against sand and dust storms, dune fixation, prevention of terrestrial soil erosion on saline grounds, windbreaks.
c) For soil desalination and reclamation of land degradation.

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