

The Effect of Irrigation on the Annual Apical Growth of the 12–14 Years Old Seed Plants of Black Saksaul

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ABSTRACT

This article discusses the ways of solving the problems of fruiting and increasing the yields, as well as obtaining high-quality standard seeds from promising seed plants of black saksaul (*Haloxylon aphyllum* (Minkw.) Iljin). It presents the results of studying the effect of irrigation and the use of fertilizers on the annual growth of the apical shoots of saksaul, and the effect of irrigation on the further stability of seed plants fruiting for sustainable seed supply for reproduction of saksaul deserts and forest amelioration of deserts. The morphological description of the soil by profiles has been given, and the effect of irrigation on the soils of the type II forest conditions has been described. This study was aimed at resolving the problem of fruiting frequency, increasing the yield and quality of promising black saksaul seed plants by determining the moisture dynamics in the one-meter thick soil layer under saksaul specimens for determining the methods, norms, and time of irrigating seed plants. Long-term observations show that well-developed specimens of black saksaul have appeared in the last 15–20 years on the roadside in some settlements, e.g., Bakbakty, Bakanas, Akkol, Koktal, Karoy, the motor road in village Kanshengel, Topar, Araltobe, Akzhar in the Almaty area, which passes through natural saksaul plantings and the soil with the formation of layered clay, sandy loam, and crushed stone. On the one hand, this was promoted by the presence of layered and well-aerated roadsides of the bulk roadbed, and on the other hand, by additional wetting from the runoff of precipitation from the asphalt pavement. Naturally, these saksaul plantings growing along the roads alone or in rows give a good yield when fruiting; seed plants may also be identified in these groups.

Keywords: Black saksaul, forest growth conditions, soil profile, soil, laboratory analysis, annual apical growth.

INTRODUCTION

Black saksaul is interesting as a species that not only is distinguished by peculiar ecology, but also has great practical significance in the desert zone. This biologically stable and durable tree species is used to fix moving sands, to protect pastures from wind erosion, to increase forage productivity of the pastures, and to protect animals from frequent winter storms [Faizov, 1980; Abdraimov, 1988; Mambetov et al., 2016].

Since black saksaul reproduces only by seeds, the issues of seed propagation are of great interest. Saksaul plantings perform important soil-protective, environment-improving, sanitary, and hygienic functions [Shamsutdinov, 1984],

contribute to the formation of stable and productive pastures, serve as the main base for distant-pasture cattle rearing [Mambetov et al., 2017]; they are used for creating artificial pastures [Sychev, 2005], they are the habitat of rare animal species, and preserve the flora.

Representatives of the *Haloxylon* genus – *Haloxylon aphyllum* and *Haloxylon persicum* – grow on the territory of Kazakhstan and occupy large areas in the Il-Balkhash region.

Many researchers have studied the anatomical structure of the *Haloxylon* genus [Dosmanbetov et al., 2018; Kabanova, Danchenko, 2017]; among Russian scientists who performed anatomical studies Lee et al. [2013] are noted. To provide a theoretical base for the recommendations

for restoring the natural ecosystems in the desert areas and ensuring stability of the natural ecosystems, it is necessary to study the anatomy and the structure of green shoots of two species of the Chenopodiaceae family (*Haloxylon aphyllum*, *H. persicum*) and to analyze the similarities and differences between the morphometric parameters and the adaptive capacity of the studied taxa.

After massive felling, saksaul plantings recover only within 30–40 years, but they can reach their former state only after a few hundred years. A good harvest of saksaul (4 – 5 points in a 6-point assessment), according to several authors [Maysupova et al., 2016; Mambetov et al., 2016], occurs once in 3–4 years.

However, according to the observations of the authors, in the Southeast of Kazakhstan (in the Southern Balkhash region), a good harvest occurred in 1999 and in 2009, i.e., once in 10 years. This is due to the intensive anthropogenic impact on saksaul plantings and the global warming.

For instance, after 1995, when switching to market relations and searching for the most optimal structure and forms of forestry management, the overwhelming part of the best black saksaul plantations in the Southern Balkhash area turned out to be sparse and weakened, and the average air temperature here increased by more than 1 °C. All this disrupted the existing regularities in the biology of saksaul, and, in addition to increasing the period between years with good fruiting, increased saksaul susceptibility to diseases and pests. In this situation, the main attention was paid to the reproduction of black saksaul as the most common species playing a fundamental role in improving the ecology of the region and at the same time being intensively destroyed.

MATERIALS AND METHODS

Particular attention was paid to the possibility of choosing forest areas with additional source of moisture, including concentration of the precipitation runoff or snow trails. Such areas may be found along the edges of saksaul plantations, and on the north side of the sandy ridges that cross the ancient alluvial plain at certain distance. Initially, these areas were visible by lush grass vegetation. In this regard, according to the Drude scale of abundance, the projective cover of the soil by grass vegetation, the composition of its abundance by the species, and grass vegetation height

expressed in cm were described. After that, three soil boreholes 1–2 m deep were made along the line perpendicular from the sandy ridges in the centers of glades at the distance of 10 m. The time of making wells was the first half of April. They were intended for determining the depth of soil wetting and identifying the contours of the area with more favorable water-physical and, therefore, forest growth conditions for saksaul forests.

Roughly, the contours of three areas with favorable water-physical conditions were determined annually. For this purpose, 100–150 soil boreholes 1–2 m deep were made. Watering of the experimental seed plants was made in groups of 6–8 and 12–14 years old seed plants along a single radial furrow 1 m from the trunk, in groups of 21–24 and 40 or more years old – in two circular furrows at the distance of 1 and 2 m from the root neck of the seed plants. The moisture content in the soil was determined using the thermal gravimetric method with the aim of studying its dynamics and the time of seed plants watering.

In the studies aimed at refining the types of forest growth conditions, works of Pashkovsky [1989] and three groups of types of saksaul were taken as the base:

1. Plain;
2. Low hills, sand ridges, hillocks and their slopes; and
3. High sand ridges, hillocks and their slopes.

During the research, the authors studied the maps of forest stands of state forestry institutions, and the routes were determined. Along the routes with the above three groups of saksaul forest types, the growth conditions of the plantings were described and the taxation characteristics of saksaul forests were determined. For this purpose, trial plots were laid with coverage of low-density (0.3 – 0.4), medium-density (0.5 – 0.6), and high-density (0.7 – 0.8) plantings in all three groups of forest types. With that, the route number, its direction, the date of laying a temporary trial plot and its coordinates were documented. Each trial plot had to have at least 100 accounting specimens of saksaul.

In addition, the following was described for each trial plot: forest type, geographical location, terrain, surrounding grounds, grass cover, including the overall projected coverage of the soil in percent, grass species, abundance by Drude, and height in centimeters.

The groundwater level (further referred to as GWL) was determined by the nearest wells; the soils were studied in accordance with the guidelines.

With that, the authors determined the thickness of genetic horizons, humidity, color, structure, consistence, mechanical composition, presence of roots, boiling from 10% HCl, inclusions, neoformations, and transition to the next horizon.

From the most typical soil cross-sections, soil samples were taken with the weight no more than 0.5 kg each. These samples were analyzed with the determination of the chemical composition of the aqueous extract.

Based on the Guidelines for Soils Classification and Diagnostics and the results of the aqueous extract analysis, the degree and the chemism of soil salinity were determined. Special attention was paid to the presence of alkali, chloride, and sodium salinification.

The chemical composition of the agrohydrological properties of the soils and the content of mobile nutrients in the soils in this region were determined by the existing reference books, and the degree of soils salinification and soils composition – based on the analysis of the aqueous extract.

The hydrological conditions of the soil were studied in accordance with the existing methods. Soil cross-sections were made in the most typical locations or in typical groups of soils, the morphological horizons of the soil were described,

and soil samples were taken for laboratory analysis. Based on the morphological description of the soil horizons and the chemical composition of the soils, the composition and salinity of soils were determined, and the lowest soil moisture capacity was identified.

Watering of the experimental seed plants was made in groups of 12–14-years-old seed plants in a single circular furrow located at the distance of 1 m from the trunk. The moisture content in the soil was determined using the thermal gravimetric method with the aim of studying its dynamics and the time of seed plants watering. The types and norms of mineral fertilizers were determined by the presence of hydrolysable nitrogen, mobile forms of phosphorus and potassium. The 12–14-years-old seed plants were irrigated with 160 and 80 liters per tree three times during the vegetation period. The 12–14-years-old seed plants grew in long-unused gardens on loamy soil.

RESULTS AND DISCUSSION

The studies were performed in territory of the Municipal Public Utilities Institution Bakanassk Forestry in the Almaty region (Fig. 1).

In recent years, cases of damage to saksaul forests by powdery mildew, gall midges, or turquoise psylla have become increasingly common. Gall midges are an isolated group of small dipterans adapted to the desert living conditions.

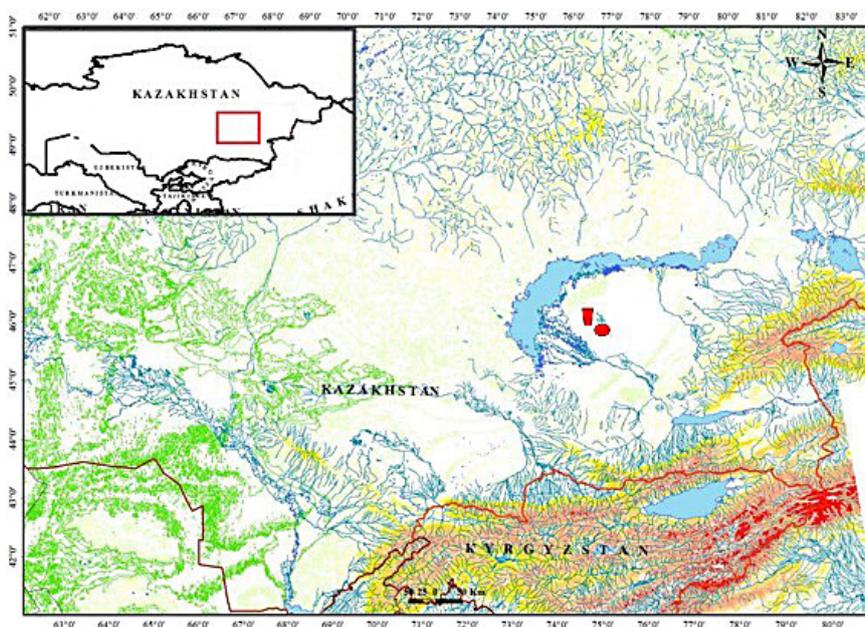


Figure 1. The schematic map of the research works location

Each species of gall midges is strictly monophagous, and develops on certain parts of the plants and causes formation of specific cockles. Adult specimens do not feed, and live only from a few hours to two or three days. They spread mainly passively, by air currents. Psylla develop in two generations a year, and some – in one generation. Their lifestyle is closely associated with the biology of fodder plants. However, even on this unfavorable background, on well-aerated and additionally humidified soils, there are single specimens and small plantations that bring fruit well and systematically, without or with few diseases and pests. First of all, these include self-seeded saksaul along the roadsides of the highways that pass through saksaul plantings, in particular, these are highways from settlement Bakbakty – settlement Bakanas – settlement Akkol – settlement Koktal – settlement Karoy, roads settlement Konshengil – settlement Topar, and settlement Araltobe – settlement Akzhar. Here within the last 15–20 years, on the road side of the highway, where the soils contain formations of layered clay, sandy loam, and crushed stone, kind of alley plantings or single well-developed specimens of black saksaul appeared. On the one hand, this was promoted by the presence of layered and well-aerated roadsides of the bulk roadbed, and on the other hand, by additional wetting from the runoff of precipitation from the asphalt pavement.

It was also repeatedly noted that small well-fruited plantings appeared in harvestless years on the light soils with high groundwater level (2–3 m). Therefore, two important factors for increasing the fruiting of saksaul were identified: 1 – the presence of loose layered soils, and 2 – additional moistening of the seed plants.

The soils were morphologically described by the cross-section P-5A-18 on the loamy soils of long-unused gardens. The description is provided below.

The tables show the results of laboratory analysis of the mechanical composition of soils under

12–14-years-old black saksaul seed plants and water extract from the loamy soil of long-unused gardens (type II), as well as the effect of irrigation on an annual apical growth of 12–14-years-old seed plants of black saksaul.

The results of the laboratory analysis of the mechanical composition of these soils are shown in Table 1.

The data on the soil mechanical composition under 12–14-years-old saksaul seed plants shown in Table 1 correspond to their morphology. Light loamy on the surface, these soils in the middle part of the cross-section become thick and heavy loamy. Their chemical composition is shown in Table 2.

Table 2 shows that these soils are medium alkaline on the surface ($P = 8.33$) and strongly alkaline in the lower part of the profile ($P = 9.05$); they are carbonate ($CO_2 = 5.79 - 6.81$), but not saline. Salts content in the dry residue amounts to 0.165–0.259%. On light hydromorphic soils without visible signs of depression, black saksaul can withstand salinification up to 2.5% by solid residue.

The growth of 12–14-years-old saksaul seed plants characterized by annual apical growth of the shoots is shown in Table 3.

As follows from Table 3, irrigation of 1–14-years-old seed plants with the norm of 160 l per tree makes the apical shoot growth significantly higher (43.4 ± 0.4 cm) than irrigation with the norm of 80 l per tree (33.6 ± 0.4).

Black saksaul forests are an integral component of the psammophytic deserts on ridge-hilly sands. They mostly occupy the depressions between the hillocks, which are, in turn, occupied by white saksaul forests.

In the structure of phytomass, the share of underground organs of black saksaul forests is up to 48%. The share of green parts is about 10%. From these relations it follows that in these formations, the lignified aboveground parts are very important. The productivity of black saksaul forests is almost four times higher than that of white

Table 1. The results of the laboratory analysis of the mechanical composition of the soils under 12–14-years-old seed plants of black saksaul

Cross-section No.	Horizon, cm	The number of fractions to dry soil, %						The sum of fractions, %	
		1.00 – 0.25	0.25 – 0.05	0.05 – 0.01	0.01 – 0.005	0.005 – 0.001	<0.001	<0.01	<0.01
P-5A-18	10 – 20	0.11	47.85	29.25	7.03	11.24	4.52	22.79	77.21
	50 – 60	0.07	31.49	10.59	12.16	25.57	20.12	57.85	42.15
	90 – 100	2.40	49.08	18.95	7.59	9.62	12.36	29.57	70.43

Table 2. The results of laboratory analysis of the water extract of loamy soils under 12–14-years-old saksaul seed plants

Cross-section No.	Horizon, cm	pH	Mg-equivalent per 100g of soil		Content in %		Mg-equivalent per 100g of soil % to dry soil								The sum of salts, %	Dense residue, %
			Na ⁺ exchange	Exchange capacity, %	CO ₂	SO ₄ gypsum	CO ₃ ²⁻	HCO ₃ ⁻	Cl	SO ₄ ²⁻	Ca ₂ ⁺	Mg ₂ ⁺	Na ⁺	K ⁺		
P-5A-18	10 – 20	8.33	4.04	14.0	5.79	1.56	-	0.72 0.04	0.40 0.01	1.36 0.06	0.50 0.01	1.50 0.01	0.33 0.008	0.15 0.006	0.16	0.17
	50 – 60	8.40	0.52	18.8	6.02	1.40	-	0.60 0.03	0.50 0.01	2.79 0.13	1.50 0.03	1.50 0.01	0.76 0.018	0.13 0.005	0.25	0.20
	90 – 100	9.05	6.38	22.0	6.81	1.33	-	0.68 0.04	0.20 0.00	2.51 0.12	1.20 0.02	1.60 0.01	0.54 0.013	0.04 0.002	0.22	0.23

saksaul forests (6.7 t/ha/year). It is mainly formed due to the growth of the underground organs. In relation to the phytomass, the productivity is more than 50%.

The productivity of forest stands is influenced by a number of factors. According to Antanaitis, et al. [1986], the age dynamics of taxation indicators is influenced by such factors as various growing conditions; the peculiarities of tree vegetation biology, species in the forest stand; the conditions in which the forest was formed; the genetic characteristics of specimens, the age structure of the population, their age; the density of the forest stand; the territorial structure of the population; the terrain; the occupied niche of the forest stand; the degree of clutter of the forest; various degrees of environmental pollution; exogenous factors (climatic, natural disasters); geographical position, altitude above the sea level; and the anthropogenic changes.

In the studies of Lear et al. [1974], all factors that influence and determine the growth and the productivity of the forest stand are divided into three groups: the influence of time, the influence of the external environment, and the hereditary qualities of the specimens, which make up a totality. At present, taking into account the factors of hereditary features of every tree and the influence of external environmental conditions is a rather difficult task in determining the dynamics of the

forest stand growth; therefore, these criteria are not taken into account.

There is a method of creating plantations of black saksaul that includes suppression of the competing vegetation, soil tillage in 1.5 m wide bands, leveling the soil surface in bands, scarification of black saksaul seeds, seeding them to the depth of 0.5–1.0 cm, harrowing after seeding, rolling and mulching the top layer, and care and formation of plantations with the density of 900 – 1,200 plants per 1 ha. The disadvantages of this method include the unacceptably long period (9 – 12 years) of obtaining seed material after sowing black saksaul seeds on improved or newly created pastures [Shamsutdinov, 1975].

In arid regions, deserts and semi-deserts are likely to respond to global climatic changes in the geomorphological, the hydrological, the biological, and the biogeochemical aspects [Lioubimtseva et al., 1998]. It was also predicted that arid regions were the most sensitive ecosystems to the global warming, and their responses were most difficult to predict [Lioubimtseva, Cole, 2006; Smith et al., 2000].

The presence of water is a key factor affecting the plant growth, the structure, and the composition of plant communities in arid and semi-arid ecosystems [Le Houerou et al., 1988; Miranda et al., 2009; Robertson et al., 2009; Sala et al., 1988; Schwinning et al., 2004; Yahdjian, Sala, 2006].

Table 3. The effect of irrigating 12–14-years-old saksaul seed plants with 160 l and 80 l per tree on the apical annual growth of saksaul

The age of seed plants, years	The type of forest growth conditions	Irrigation norm per 1 seed tree, l	Annual apical growth, cm	Differences between the variants, cm	Significance of differences
12 – 14	Type II (loamy on long-unused gardens)	160	43.4 ± 0.4	9.8	17.5
		80	33.6 ± 0.4		

However, there is a global limit to the net primary productivity of land ecosystems [Le Bauer, Treseder, 2008; Vitousek, Howarth, 1991], including desert ecosystems [Hall et al., 2011; Hooper, Johnson, 1999; Krueger-Mangold et al., 2004; Yahdjian et al., 2011]. In addition, there were reports about the relationship between the effect of the water and adding nitrogen on the growth of desert plants, the structure, and the composition of ecosystem communities [Fan et al., 2013; Ladwig et al., 2012; Schmiedel et al., 2012].

Snowfall is a special form of precipitation, and its melting may feed the water in the soil and promote the growth and development of the plants [Wang et al., 2006]. Snow accumulation and removal is currently influenced by the global warming, which significantly accelerates snow melting [Dye, 2002; Rikiishi et al., 2004]. This change may lead to an earlier beginning of the vegetation season [Shabanov et al., 2002].

In arid and semi-arid ecosystems, plants' behavior is limited by water and nitrogen supply [Zhang, Zak, 1998]. However, the data also show that productivity is not directly dependent on the water availability [Gutierrez, Whitford, 1987].

It has been found that the genetic quality of the seeds of *Haloxylon aphyllum* was not associated with the toxic effects of salt but with the deficit of available water, which is formed on the background of the arid climate and the deep groundwater level, which is typical for sandy soils in the lowland and upland areas of the desert, or the high salt content on solonchaks [Shuyskaya et al., 2012]. Consequently, in terms of the deficiency of available water, the stressful conditions for *H. aphyllum* are soils with weak and strong salinification, whereas good living conditions will be the soil that contains 1.85–1.93% of water-soluble salts in the 1 m thick layer [Shamsutdinov, Shirinskaya, 1963].

CONCLUSION

Thus, according to the studies performed in black-saksaul forests of the Southern Balkhash area, the following conclusions can be drawn:

1. The used norms of irrigation into circular furrows on the best loose-layered soils have made it possible to ensure the optimal level of moisture, that is, not lower than 40% of the norm for more than 15–23 days in the one-meter layer under 12–14 years old seed plants.

2. On heavy soils, the optimum moisture level is kept for no more than 15 days only in the 0–60 cm thick soil layer.

Given the age of the seed plant, the soil conditions, the depth of soil wetting, and the duration of soil moisture preservation, the following norms for watering black saksaul are recommended:

- for 12–14 years old seed plants – 160 l per tree, into a single-ring furrow; and
- given the recommended norms, it is suggested to water the seed plants on light layered soils 3–4 times, and on heavy soils – 5–6 times per growing season.

In addition, the promising developments on the irrigation norms will be used in the future in a complex for obtaining seed material, mainly from superior saksaul trees, initial check of their offspring in a nursery, followed by the use of the best offspring for laying seed plantations and raising the level of saksaul reproduction in Kazakhstan.

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