OnLine Journal of Biological Sciences

Original Research Paper

Growth and Development of the Black Saxaul Depending on Tillage in Arid Conditions of Kazakhstan

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Article history
Received: 27-11-2022
Revised: 30-03-2023
Accepted: 10-04-2023

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Abstract: The study aimed to develop technology for the artificial cultivation of saxaul plantations with minimal labor and money, allowing for achieving a high survival rate, growth intensity, and crop development. The Samara State Institution for the Protection of Forests and Wildlife studied the effectiveness of creating forest plantations using various tillage methods. Four soil preparation systems served as experiment variants. The authors concluded that sweeping tillage to a depth of 40 cm was the best option for growing black saxaul forest plantations because it ensured high efficiency and increased plant growth and survival. Preliminary soil preparation increased saxaul plant height growth by 40.3-48.5% compared to the control variant without soil preparation. Mouldboard fall plowing to a depth of 25-27 cm and sweep tillage to a depth of 40 cm increased the survival rate of black saxaul plants by 13.5% and 16.8%, respectively, compared to the variant without soil preparation. The condition of forest plantations in variants with preliminary soil preparation corresponds to the C_1 and C_2 indices, whereas without soil preparation, the index decreases to C_3.

Keywords: Survival Rate, Soil Conditions, Forest Vegetation, Dynamics of Growth and Development, Forest Plantations

Introduction

The creation of stable and long-lasting protective forest plantations in arid conditions of Western Kazakhstan remains a difficult issue due to the extreme continental climate, the large complexity of forest-growing properties of soils, the low use of agricultural technology in cultivation, and the lack of measures for their maintenance and protection (Yessimbek *et al*., 2022; Yesmagulova *et al*., 2023).

A significant increase in planting areas necessitates a more detailed study of the seasons and planting dates of the saxaul so that part of these works can be carried out in the autumn which would remove the existing load when performing forest reclamation work in arid conditions. The need to study this issue is also caused by the fact that no one has conducted special studies on the timing of the creation of saxaul plantations by planting seedlings in this region.

The effectiveness of a tight planting schedule in the spring period is explained by the rapid deterioration of growing conditions caused by the increase in temperature and the desiccation of the upper soil horizons. In the autumn period, on the contrary, there is a decrease in the intensity of the temperature regime (Yessimbek *et al*., 2022). To identify the optimal way to create plantations, it is necessary to choose different methods of tillage. Tillage for the cultivation of saxaul can be carried out by several methods. Analysis of scientific research and literature sources (Mambetov *et al*., 2016) shows that preliminary soil preparation has a positive effect on the process of preserving soil moisture. For a good moisture content in the soil, it is preferable to prepare the soil according to the system of 1-year bare fallow. An important factor in soil preparation is the depth of its plowing. Studies (Tomeichuk and Baranov, 2017; Dosmanbetov *et al*., 2022) also found that deep plowing of the soil contributes to greater preservation of its moisture. Deep plowing in combination with 1-year bare fallow contributes to the greatest accumulation of soil moisture. Two-year fallow does not give positive results in maintaining soil moisture and from an economic point of view does not fully justify itself.

It should be noted that spring plowing does not have a positive effect on the preservation of soil moisture, which is explained by the desiccation of the soil during the growing season, and autumn plowing aggravates this process.

Studies have shown that 1 hectare of saxaul at the age of 4 years absorbs 1,158.2 and 1,547.8 kg of carbon dioxide, respectively, and at the same time emits 835.4 and 1,116.4 kg of oxygen, respectively. Carrying out large-scale afforestation works on the drained bottom of a water body will bring us closer to reducing the problem of global warming (Dosmanbetov *et al*., 2020).

Therefore, the identification of the best techniques and methods of their creation provides for the development of more rational and advanced cultivation and maintenance technologies that ensure the formation and improvement of their reclamation and environmental efficiency. Several researchers have pointed out the complexity of creating such plantations, especially in hydrothermally extreme conditions, where their creation is not always successful (Ramazonov, 2017; Bakirov *et al*., 2020).

In the period 2018-2020, the corporate fund "the biodiversity conservation fund of Kazakhstan" prepared untreated desert soil for reclamation in an area of 7,500 ha: Cutting 25 cm wide furrows with simultaneous para-plowing to a depth of 40 cm, after which black saxaul plants were sowed and planted in those areas (BCFK, 2020).

According to research data (Dosmanbetov *et al*., 2020), it is recommended to carry out tillage in the form of mouldboard fall plowing to a depth of 25-27 cm. Depending on the mechanical composition of the soil, various methods of tillage are used.

Belitskaya *et al*. (2017) in the conditions of the Caspian Sea, the best results in the survival and growth of black saxaul in forest strips are obtained by spring planting with annual seedlings. By the end of the first year, seedlings reach an average height of 0.3-0.5 m, an average of 1.0-1.8 m in the second year, and 2.0-2.5 m in the third. At the age of 5-6 years, the height of the saxaul reaches 3.0 m.

For the conditions of southwestern Kazakhstan on degraded desert pastures, (Abduraimov, 2011) also recommends carrying out tillage in the form of mouldboard fall plowing to a depth of 18-22 cm. The same data have been confirmed by experiments conducted in the Northern Aral Sea region by Uteshkaliev and Akhmetov (2016); these authors state that when growing artificial plantings of saxaul, it is preferable to prepare the soil according to the system of mouldboard fall plowing on a depth of 25-27 cm, which increases the survival rate of plants by 3.0-5.3%; the growth of saxaul in height increases in the range of 7.4-11.5% compared with spring plowing and the system of 1-year bare fallow.

The vegetation of the Mangystau region develops in very harsh natural conditions: Aridity of the climate, large amplitudes of fluctuations in daily and annual air temperatures, and a sharp lack of moisture in combination with a wide spread of saline soil-forming and underlying rocks. All this determines the formation of vegetation cover characteristic of deserts.

The object of the study wa**s** black saxaul (*Haloxylon aphyllum* (*Minkw.*) *Iljin*), which is part of the Haze family (*Chenopodiaceae*). Saxaul is one of the few desert plants that grow on salty soils and can survive in an extreme continental arid climate. In addition, the density of the saxaul trunk is 2 times higher than the density of deciduous and coniferous trees of the temperate climatic zone, which automatically increases the amount of carbon retained by managed saxaul forests compared to deciduous and coniferous forests of Russia and Europe.

This is a large shrub, sometimes reaching 7-10 m in height. It has very long roots that feed on groundwater, so the shoots are saturated with moisture; the trunk of the plant is curved, but has a smooth surface, and can reach 1 m in diameter. The crown of the trees is quite massive and green, but their leaves appear in the form of scales, and photosynthesis is carried out with the help of green shoots. When the plant blooms, it has flowers from pale pink to crimson. It blooms in April-June and bears fruit in September. It occurs on takyrs and takyr-like gray soils but forms smaller shrubs here (Yessimbek *et al*., 2022).

The vast territory of semi-desert and desert zones of the Mangystau region is a serious prerequisite for the organization of scientific research on agricultural techniques for growing saxaul plantations. To date, effective ways of restoring saxaul forests have not yet been developed. A review of foreign literary sources shows that the available information on the cultivation of arid crops is regional and is often contradictory, which hinders the process of restoration of saxaul forests. While in Central Asia there is quite a lot of practical experience in the afforestation of sands and pastures, and in the regions of the Northwestern Caspian Sea, the black saxaul plantations being created are characterized by high and stable survival and successful growth, in Kazakhstan these works are at the initial stage of development.

It is necessary to develop such a technology for growing plantations that would consider the forestry and agriculture perspectives and would allow both wood and pasture land to be obtained at the same time.

The scientific novelty of our study is as follows: For the first time in the arid conditions of Western Kazakhstan, the most rational methods of soil preparation have been established, the predominant importance of planting crops in comparison with sowing has been observed, the optimal timing of the planting has been determined, new parameters for the placement of seedlings on the forest-cultivated area have been determined, and effective technologies for agrotechnical crop care have been developed. Scientific substantiation of technologies for creating long-lasting forest plantations is of great economic importance since the use of such systems will significantly increase the forest cover of the territory and improve the living conditions of the population.

The study aimed to develop a technology for artificial cultivation of saxaul plantations with minimal labor and money, which allows for achieving a high survival rate, growth intensity, and crop development.

Materials and Methods

Study Location and Period

In the Samara State Institution for the Protection of Forests and Wildlife of the Mangystau region from 2020 to 2021, we conducted a study of the effectiveness of creating forest plantations using various tillage methods.

Object and Design of the Study

The object of the study was forest plantations of the black saxaul (Fig. 1) in arid conditions of Western Kazakhstan (Mangystau region).

The program of our work provided for the study of the effectiveness of previously created saxaul forest plantations with various methods of soil preparation. The following observations were carried out on the cultivated forest area:

- Determination of survival, growth, and condition of plantations on trial areas during the autumn inventory. At that time, along with measurements of plant height, the dimensions of the crown projection in two mutually perpendicular directions (along and across the row) were recorded. At least 35 plants on each of the test sites established in three-fold repetition were measured. The height was measured with a rail, and the crown projections were measured with a rail or tape measure with an accuracy of 5 cm. The survival rate was determined by a continuous enumeration of shrubs on trial sites

The following soil preparation systems served as variants of the experiments:

- Mouldboard fall plowing to a depth of 25-27 cm
- Mouldboard spring plowing to a depth of 25-27 cm
- Sweep tillage to a depth of 40 cm
- No-tillage (control)

In the zone of insufficient moisture, the successful cultivation of forest plantations is largely determined by the proper preparation of the soil, which should be aimed at improving its physical and biological properties and thereby creating favorable conditions for the survival and growth of young plants. Tillage improves its physical and mechanical properties and is aimed at destroying weeds, providing moisture to the lower horizons, which contributes to a more powerful growth of root systems of young plants.

When preparing the soil for creating forest plantations, the types of growing conditions, the state of forest-cultivated areas, and the biological properties of the species introduced into the plantations should be considered.

The survey of forest stands was carried out by the method of reconnaissance survey for initial acquaintance with the natural conditions and vegetation cover of the research area. During the reconnaissance, changes in vegetation, relief, and soil along the route intersections were briefly characterized in the form of brief notes. Based on reconnaissance, temporary test areas were laid in the most characteristic areas to clarify the relationship of vegetation with the growing conditions.

Trial areas in kind were marked with labels indicating the year of the bookmark, the number of the trial area, and the type of plantings, and were tied to a permanent landmark.

For each type of planting or plot, three test areas were laid, on which the survival rate, height, crown projection diameters along and across the row, and condition were determined. The total height of the plants was determined by a measuring rail or an HEC Haglof altimeter (Sweden). The diameter of the trunk and shoots was measured with a measuring fork or caliper at the soil surface and a height of 130 cm (Zhaglovskaya *et al*., 2017).

The survival rate was determined by a continuous enumeration of shrubs on test areas for each strip or variant after the end of the growing season. The assessment of the condition of saxaul plants in all test areas was evaluated on a scale where the increments were determined by six characteristic features: C_1-C_3: Increments in height more than 30, from 5-30 and less than 5 cm, respectively, C_4: No apical increment, but present assimilation shoots of the current year in the lower part of the plant, C_5: No assimilation shoots of the current year, but the plant has not shrunk and remains alive and C_6: A dead (dry) plant.

Fig. 1: Three-row forest plantations of the black saxaul

Table 1: Determination of the granulometric composition of soils in the field

Granulometric type of soils	Properties of the rolled lump
0: Sand, non-plastic	The soil cannot be rolled up into a lump or a string
1: Sandy loam, very slightly plastic	The soil rolls into a fragile lump but does not roll into a string
2: Light loam, slightly Plastic	The soil rolls down into short thick cylinders, “sausages “that crack when bent
3: Medium loam, medium plastic	The soil rolls into a string with a diameter of 2-3 mm, which easily breaks when further rolling or cracks when bending
4: Heavy loam, very plastic	The soil rolls into a thin string, less than 2 mm in a meter, which breaks when it is bent into a ring with a diameter of 2-3 cm
5: Clay, highly plastic	The soil rolls into a long, thin string, less than 2 mm, which bends into a ring with a diameter of 2-3 cm without breaking its integrity

All information was entered into a special inspection card. The card reflects all the inspection data that make it possible to make a full assessment of the plantation and outline measures for its effectiveness and sustainability (forestry, agrotechnical, etc.), as well as its expediency of maintenance or reconstruction.

Collection and Analysis of Samples

To characterize soil conditions, soil sections were established with their description and sampling to determine water-physical and chemical properties. Genetic horizons were described by the following morphological features: Coloration, structure, power, addition, structure, neoplasms, inclusions, bubbling from HCl, and mechanical composition. The incisions were established to a depth of 150-160 cm. Samples were taken from the genetic horizons for chemical analysis.

The mechanical composition and salinity of soils were determined according to the following scale according to Kuz’mina and Treshkin (2013) (Table 1).

Analyses of soil samples were carried out in a soil laboratory with the determination of total humus, total nitrogen, mobile forms of nitrogen, nitrates, and calcium; pH of water extract; gypsum in the soil, exchange capacity, maximum hygroscopicity, exchange bases of the soil (non-carbonate and carbonate), and the mechanical composition.

Experimental sites were established on the selected plots, where an analysis of the course of plant growth in height was planned with the determination of survival rate. During the inventory, the survival rate of plants and their condition were determined by the formula:

$$p = \frac{(zh + \frac{1}{2}C)}{Ch} x\,100$$

where, *P* was the survival rate, %; *Zh* was the number of healthy plants, pcs.; *C* was the number of dubious plants, pcs., and *Ch* was the number of planting (sowing) places, pcs.

From the accompanying observations, herbaceous (weed) vegetation was considered. The determination of the occurrence of weed vegetation was carried out according to Fetyukhin's methodological development (Fetyukhin *et al*., 2018).

Observations of the weed growth were carried out on accounting sites measuring 1.0×1.0 m, which were tied to permanent marks in the plantations and established in the inter-row positions of forest plantations evenly every 10 m in three-fold repetition. At each repetition, seven accounting sites were established, where the height of the main types of weeds, the number, and the projective coverage were noted. Weed accounting was carried out in spring every 15 days and in summer every month. The projective coverage was determined by eye using a grid (10×10 cm cell) with an accuracy of 10%. The occurrence of weed species was determined as a percentage (Shagaipov and Bulakhtina, 2011).

Tillage was carried out when the height of weeds reached 10-12 cm and their average number was more than three-four pieces per square m. After tillage for 5-6 days at the same sites, the number of preserved specimens was taken into account, which made it possible to evaluate the effectiveness of tillage tools.

The survival rate, growth, and condition of plantings, depending on the multiplicity of agrotechnical care, were determined during the autumn inventory of plantations.

Statistical Analysis

The analysis of biometric data was performed in Excel using the statistical methods.

Results

This study aimed to develop a technology for artificial cultivation of saxaul plantations with minimal labor and money, which allows for achieving a high survival rate, growth intensity, and crop development.

Survival Rate and Growth of 1-Year Black Saxaul Plantations

The determining indicators in assessing the effectiveness of crop cultivation are the survival and growth of plants. In our studies, these indicators are closely interrelated with the method of preliminary soil preparation (Table 2, Fig. 2).

Table 2: Survival rate and growth of 1-year black saxaul plantations depending on the method of soil preparation

		Medium		
Variant no.	Tillage system	Survival rate, %	Height, cm	Status, points
1	Mouldboard fall plowing to a depth of 25.0 to 27.0 cm	66.7	53.8±2.4	C_1
2	Mouldboard spring plowing to a depth of 25.0-27.0 cm	57.4	48.4±2.1	C_2
3	Sweep tillage to a depth of 40.0 cm	71.2	56.9±2.6	C_1
4	No tillage (control)	47.6	42.4±1.9	C_3

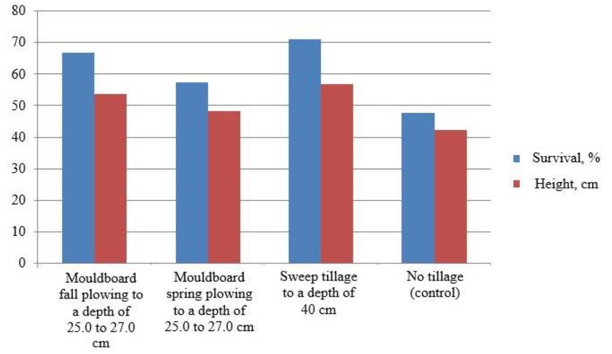

Fig. 2: Survival rate and growth of 1-year black saxaul plantations depending on the method of soil preparation

As can be seen from Table 2, the best survival rate and growth of black saxaul seedlings in the first year of plant production, in our opinion, is explained by the intensive use of nutrition elements of the humus horizon of the soil. With mouldboard plowing, the upper humus horizon is rotated into the lower layers of the soil, and with a boardless system, saxaul seedlings use all the nutrition elements of the humus horizon. During mouldboard plowing, the assimilation of nutrients by plants occurs at a later date, when the roots of plants develop deeper, and reach the horizons of the inverted formation, as a result of which the process of more complete assimilation of nutrients of the humus horizon occurs.

In this respect, the data on the growth of annual crops in height is significant. The best growth of the black saxaul is visible in areas where soil preparation was carried out to a depth of 40 cm. Here the saxaul has a greater increase than on the plowed areas, to a depth of up to 27 cm, which is due to better moisture availability provided by deep tillage.

The difference in gains is 5.5 and 14.9%, respectively, in favor of deep tillage. An effective survival rate (71.2%) was also noted in plantings where soil preparation was carried out by sweep tillage to a depth of 40 cm, compared with the mouldboard fall plowing to a depth of 25-27 cm (66.7%). The shrubs planted after mouldboard spring plowing (57.4%) and without soil preparation (47.6%) took root worse than others. The difference in the seedling survival rate increase by mouldboard fall plowing in comparison with mouldboard spring plowing is 13.9%, and the difference with the variant without soil preparation is 28.6%. Deep tillage has a positive effect not only on survival but also on the intensity of growth of saxaul plants.

A noticeable increase in the height gain after tillage to a depth of 40 cm, compared with other variants, ranges from 5.5% (fall plowing) to 14.9% (spring plowing). The growth of saxaul in the variant with fall plowing is 10.1% more than in spring plowing. The drop-off of seedlings planted without soil preparation is 9.8, 19.1, and 23.6% higher, respectively than in similar variants created with soil preparation. The average height of plantations varies from 56.9 cm (tillage to a depth of 40 cm) to 48.4 cm (spring plowing), whereas without soil preparation it is 42.4 cm.

This can be explained by the fact that in variants without soil preparation, there is an acute shortage of moisture in the soil and the saxaul has a restructuring of the water regime and other functions, thereby, as it were, a physiological barrier emerges, thanks to which growth processes are suppressed and, consequently, the plant adapts to unfavorable conditions.

Survival Rate and Growth of 2-Year Black Saxaul Plantations

When preparing the soil for forest plantations, the types of growing conditions and the state of forest cultivated areas were taken into account, while the survival rate and plant growth were the determining indicators in assessing the effectiveness of crop cultivation (Table 3, Fig. 3). As can be seen from Table 3, the best growth of black saxaul in 2-year plantations is seen in areas where soil preparation was carried out to a depth of 40 cm (variant 3) than by mouldboard plowing to a depth of 25-27 cm (variants 1, 2). Here, the saxaul has a height of 125.4 cm, which is 5.4 and 14.4 cm higher, respectively, compared to variants 1 and 2. The worst growth of the saxaul is observed in variant 4 (no soil preparation), compared with tillage to a depth of 40 cm, where the difference in growth is 40.5 cm, while with tillage to a depth of 25-27 cm, the average height increases by only 26.1 and 35.1 cm, respectively, compared to the variant without soil preparation. From the table data, it can be seen that the average height of plantations varies from 125.4 cm (tillage to a depth of 40 cm) to 111.0 cm (spring plowing to a depth of 25-27 cm), whereas without soil preparation it is only 84.9 cm or 23.5-32.2% lower.

Table 3: Survival rate and growth of 2 to 3-year black saxaul plantations depending on the method of soil preparation

Variant no.	Soil preparation system	Annual averages: The survival rate, % 2020	2021	Height, cm 2020	2021	Crown projections, cm 2020 Along the row	2020 Across the row	2021 Along the row	2021 Across the row	Status, points
1	Mouldboard fall plowing to a depth of 25.0-27.0 cm	45.2	45.2	120.0±5.1	131.4±5.9	124.0±5.2	125.5±5.3	136.8±6.0	137.9±6.1	C_2
2	Mouldboard spring plowing to a depth of 25.0-27.0 cm	40.5	40.5	111.0±4.5	117.4±5.4	109.6±4.4	111.4±4.5	115.8±5.3	118.2±5.4	C_2
3	Sweep tillage to a depth of 40.0 cm	48.5	48.5	125.4±5.3	139.0±6.2	120.6±5.1	121.9±5.1	138.9±5.9	139.7±6.0	C_1
4	No tillage (control)	31.7	31.7	84.9±3.7	93.6±3.9	76.8±3.1	80.4±3.5	85.6±3.7	88.7±3.8	C_3

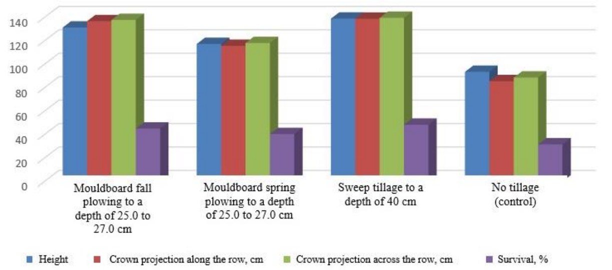

Fig. 3: Survival and growth of 3-year black saxaul plantations depending on the method of basic soil preparation

Deep tillage has a positive effect not only on the intensity of growth of saxaul plants but also on survival. The best survival rate (48.5%) was also noted in plantings where the soil preparation was carried out by sweep tillage to a depth of 40 cm, compared with the mouldboard fall plowing to a depth of 25-27 cm (45.2%).

Seedlings planted after mouldboard spring plowing lag slightly behind in survival (40.5%). Plantations created without soil preparation have taken root much worse than others. The difference in their survival rate from other variants ranges from 8.8-16.8% downwards. It is also clear from the numerical indicators that the growth of the crown both along and across the row depends on the method of soil preparation, and in our experiments, the crown is wider with tillage (109.6-125.5 cm) than without soil preparation (76.8-80.4 cm), while tillage also positively affects the increase in crown closeness.

The condition of 2-year black saxaul plantings is estimated by the index C_1 (an increase of over 30 cm) in variants with preliminary soil preparation, and in the variant without soil preparation, this index is reduced to C_2 (an increase from 5-30 cm).

Survival Rate and Growth of 3-Year Black Saxaul Plantations

As can be seen from Table 3 and Fig. 3, the best height of 3-year plantations of the black saxaul is traced in the variant with sweep tillage, where the height of the saxaul is higher than with mouldboard fall plowing, spring plowing, or without tillage (control) by 7.6, 21.6 and 45.4 cm, respectively.

The best indicators for the length of the crown projection both along and across the row were also noted for sweep tillage to a depth of 40 cm, where the length of the crown along the row was 2.1, 23.1, and 53.3 cm longer than in variants 1, 2, and 4, respectively.

The condition of 3-year black saxaul plantings is assessed by the index C_1 and C_2 (an increase of more than 30 cm and from 5-30 cm) in variants with preliminary soil preparation, and in the variant without soil preparation, this index is reduced to C_3 (an increase of less than 5 cm).

Discussion

The success of growing forest plantations largely depends on compliance with the peculiarities of their agrotechnical creation and consideration of adverse factors that negatively affect plant survival. Based on long-term research by several scientists (Khlustov and Bedareva, 2009; Kuz'mina and Treshkin, 2013) in rain-fed conditions, methods of tillage have a significant impact on the survival and further preservation of plants. Thus, the survival rate of plants with deep (35-40 cm) boardless plowing was 86%, and in the control area (ordinary plowing to a depth of 22-25 cm) the survival rate was 80%, and in the second year, the survival rate was 73 and 55%, respectively. The same patterns were demonstrated by Salmukhanbetova *et al.* (2021) in their observations in the Caspian region.

Concerning the method of creating saxaul plantations (sowing, planting), most researchers who have studied the success of creating plantations by planting seedlings and sowing seeds have concluded that reliable plantings with good preservation can only be obtained by planting the seedlings with care both in rows and between rows and on the edges. As Alimbetova *et al*. (2020) note in the Aral Sea region, the best way to grow saxaul on sandy loam is to plant seedlings grown in a nursery from seeds of local origin.

Abdurakhimov (2018), summarizing the experience of creating saxaul forest plantations in the sands of Central

Fergana, concludes that the effectiveness of spring plantations with a density of more than 1,000 pcs./ha is almost twice as high as autumn ones. The advantage of spring plantations is undeniable: They are 1.5 times more effective than autumn ones. The effectiveness of planting is almost 2.5 times higher than sowing. Plantations with a density of more than 750 pcs./ha occupy 76% of the planting area and only 9.3% of the sown area. The author recommends sowing saxaul in 15-20 days after the transition of the average daily temperature on the soil surface through 0°C and planting at an air temperature above 5°C. Shamsutdinov *et al.* (2016) suggest sowing saxaul seeds to a depth of 0.5-1.5 cm so that the seeds are placed simultaneously with sowing or immediately after sowing to the recommended depth. According to Shamsutdinov *et al*. (2013), during frosts with temperatures below -5°C, seedlings, where the seeds are planted at a lesser depth, die first of all. Autumn seeds have no advantage over early spring ones. Seedlings should be planted in early spring, immediately after the cessation of frosts. With such a planting period, seedlings have a survival rate of 85-95%. In the semi-desert zone of the Dagestan Autonomous Soviet Socialist Republic (ASSR) and the Mangistau region of the Republic of Kazakhstan, planting and sowing were tested in different agrotechnical terms, based on which the authors Kudabaeva (2010); Mukanov and Uteshkaliev (2016) concluded that planting should be carried out in the spring using standard healthy annual seedlings of black saxaul. Sowing is successful only in years with favorable climatic conditions. In their research, Khusainov *et al*. (2001) note that autumn plantings are inferior in their survival rate to spring plantings made during the first 12 days after the defrosting of the soil, that is when there is a greater supply of moisture in the soil, consisting mainly of winter precipitation.

In our study, it was noted that the lower survival rate and growth of the black saxaul were noted in the variants with a depth of tillage of 25-27 cm. Moreover, the lowest indicators were noted in the variant with spring plowing. In the control variant (without tillage), the plants had the worst indicators. A noticeable increase in plant height with a tillage of up to 40 cm, compared with other variants, ranges from 5.5% (fall plowing) to 14.9% (spring plowing). The difference in the seedling survival rate increase by mouldboard fall plowing in comparison with mouldboard spring plowing is 13.9%, and the difference with the variant without soil preparation is 28.6%. This can be explained by the fact that in the variant without soil preparation, there is an acute shortage of moisture in the soil, and with deep tillage, moisture availability increases, which favorably affects the survival and growth of black saxaul. Such an increase in moisture availability with deep tillage is also observed in other studies, such as Cai *et al.* (2014); Ovalle *et al*. (2020); Wang *et al.* (2021).

Conclusion

Analyzing the data obtained on the growth and survival rate of 3-year saxaul plantations, the following conclusions can be drawn:

- For growing black saxaul forest plantations, it is best to carry out sweep tillage to a depth of 40 cm, which ensures high efficiency and increases the growth and survival of plants
- Preliminary soil preparation increases the growth of saxaul plants in height by 40.3-48.5%, compared with the control variant (without soil preparation)
- Mouldboard fall plowing to a depth of 25-27 cm and sweep tillage to a depth of 40 cm increase the survival rate of black saxaul plants by 13.5 and 16.8%, respectively, compared with the variant without soil preparation
- The condition of forest plantations in variants with preliminary soil preparation corresponds to the indices C_1 and C_2, whereas without soil preparation the index decreases to C_3

Prospects for further research in this area could be relevant as the results of research on the agricultural technology of creating forest plantations of saxaul can be used by design organizations in the development of projects for artificial crop cultivation in arid conditions, as well as by state forestry institutions of Western Kazakhstan in the practice of forestry.

Acknowledgment

The authors thank the reviewers for their contribution to the peer evaluation of this study.

Funding Information

The authors have not received any financial support or funding to report.

Author’s Contributions

All authors equally contributed to this study.

Ethics

This article is original and contains unpublished material. The corresponding author confirms that all of the other authors have read and approved the manuscript and no ethical issues are involved.

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