https://doi.org/10.31489/2024BMG4/14-26

UDC 581.522.4:582.662 Received: 29 August 2024 | Accepted: 12 September 2024

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Main direction of optimization of agrotechnics of growing seedlings of woody plants with closed root system in Mangistau desert

The objective of this study is to optimize the agricultural technology of growing seedlings of woody plants with a closed root system in the arid conditions of Mangistau by conducting field experiments. Based on the dispersion and correlation analysis of the collected research material, it was concluded that the following agricultural practices are the most preferable in terms of biometric and physiological indicators of growth and development of woody plants: 1) Maintaining the pre-irrigation level of soil moisture within 70–80 % of the full field moisture capacity, 2) Mixing plant and peat soil in a ratio of 1: 1 and 3) Monthly fertilizing with mineral complex fertilizer at the rate of 75 g / m2. The most effective covering materials in the conditions of the Mangistau desert for preventing moisture evaporation under green spaces are such covering materials as Zeba super sorbent, sludge from treatment facilities and medium and fine gravel. The results of the research were successfully tested during mass propagation of 107 species, forms and varieties of the most promising introduced plants from 32 genera and 17 families (65,340 containers in total).

Keywords: optimization, agricultural technology, woody plants, seedlings, containers, field experiment, survival rate, growth.

Introduction

Despite significant successes of Mangyshlak Experimental Botanical Garden (MEBG) on introduction and acclimatization of plants in landscaping and horticultural practice of various organizations in Mangistau is widespread use of cheap imported planting material, which is obviously unpromising, poorly resistant and low-decorative in local conditions, while proven for decades species and varieties do not find widespread use despite all the advantages and economic effect of their introduction. At present, the network of tree and shrub nurseries in Mangistau oblast is poorly developed due to the shortage of irrigation water. The nurseries mainly grow a narrow assortment of trees and shrubs and sell their seedlings and seedlings with bare root system, which significantly reduces the level of rooting of plants.

In our opinion, the most promising way to solve the problem of reproduction of both widely used in landscaping and new species of fruit and berry and ornamental trees and shrubs in unfavorable climatic conditions of the Mangistau desert is the cultivation of their planting material with closed root system (CRS) — in containers, vases, briquettes, pots and others. This guarantees not only a very high survival rate of crops (up to 100 %), but also significantly lengthens the terms of planting works, reduces the consumption of scarce and very expensive (over 200 tg/m^3) irrigation water due to local moistening of soil and reducing losses from infiltration and evaporation.

Comparative analysis of domestic and world experience of growing seedlings and saplings of fruit and berry and ornamental plants with closed root system (CRS) on the basis of literature sources [1–7] has shown that in the practice of nursery farming for a fairly short period of time accumulated a fairly large research material, which is mainly aimed at solving the problems of forest growing and reforestation in forest and forest-steppe natural zones and are not quite suitable for extra-arid climate, saline and low-humus soils of Mangistau in terms of plant assortment, regular irrigation regime and, in general, agrotechnics of cultivation. In this regard, in the botanical garden within the framework of research work on the grant theme: “Development of scientific-methodological and practical bases of cultivation and creation of nursery of fruit and berry and tree ornamental plants with closed root system in the conditions of the Mangistau desert”, the task of clarification and optimization of basic agrotechnical methods in relation to the desert zone of the region was set on the basis of laying field experiments with variants of irrigation regime, methods of soil substrate preparation, doses of mineral fertilizers and types of moisture management.

Experimental

The objects of research were 9 botanical species and forms of different degree of stability, growth forms, systematic affiliation and geographical origin, for which biometric and physiological indicators of growth and development were determined in field experiments on the study of agrotechnics and variance analysis of collected materials was carried out: *Platycladusorientalis* (L.) Franco, *Ulmus pumila* L., *Ailanthus altissima* (Mill.) Swingle, *Armeniaca vulgaris* Lam., *Salix alba f. pendula*, *Populus bolleana* Lauche., *Fraxinus lanceolata* Borkh., *Ligustrum vulgare* L. and *Gleditsia triacanthos* L.

The aim of the research is to optimize agrotechnics of growing seedlings of woody plants with closed root system in arid conditions of Mangistau by means of field experiments.

Drawing up the schemes of field experiments was based on the methodology of experimental work of B.A. Dospekhov [8]. Taking into account the dominating in Mangistau conditions limit factors of soil moisture deficiency and soil poverty, as well as the special importance of substrate preparation quality in growing planting material, the main field experiment is laid out two-factor, including simultaneously the options of maintaining pre-watering soil moisture and mixing plant soil with peat substrate. Three variants were chosen for soil moisture: 1) Maintaining pre-watering soil moisture level during the growing season within 50–60 % of the lowest (full field) moisture capacity (MC); 2) 60–70 % of MC; and 3) 70–80 % of MC. On preparation of soil substrate 4 variants of mixing plant and peat soil were laid down: 1) 1: 2; 2) 1: 1; 3) 2: 1 and 4) control (without peat addition).

To study the reaction of plants to the application of complex mineral fertilizer, a separate one-factor experiment consisting of 5 variants was set up: 1) application of mineral complex fertilizer kemira “Spring-Summer” at the rate of 25, 2) 50, 3) 75; 4) 100 g/m^2 monthly for plant feeding; 5) control (without feeding).

Repetition of experiments is 4-fold. On each of them 5 specimens of trees and shrubs were placed. In total, 3060 units of planting material were planted in vases with a useful volume of 8 liters in the field experiments.

Standard peat lime peat substrate of “Suliflor SF0” brand with neutral medium reaction (pH — 5.5 — 6.0), fine fraction, with NPK content — 100-50-100, produced in Lithuania, was used as an organic fertilizer. Structurally, 80 % of it consists of organic matter, which is a mixture of lowland and upland peat. For plant feeding was chosen complex mineral granular fertilizer Kemira “Spring-Summer” prolonged action, containing all the necessary macro- and microelements in the optimal ratio (NPK — 11,3-12-28, S, Ca, Mn, Cu, Mo, Mo, B, Fe, Zn), produced by CJSC “KemiraAgro” (Russia).

In general, 16-17, 60–70 — 26-27 and 70–80 % of MC — 39-40 plant irrigations were carried out during the irrigation season on the experiment variant 50-60 % of MC. Inter-irrigation period averaged 10-11, 6-7 and 4-5 days, respectively.

At the end of the growing season, height, root neck diameter, length, width, leaf area and weight were determined in all experimental plants. The rooting ability of introducers was calculated based on the results of their fall inventory.

The following methods were used for physiological experiments and observations: chlorophyll content in plant leaves by T.N. Godnev on a spectrophotometer [9]; total water content of leaves — by drying leaves to constant weight at a temperature of 100–105°C; transpiration intensity by A.A. Ivanov [10] and leaf plate area — by specific area.

Statistical processing of the obtained results was carried out according to the method of G.F. Lakin [11] with the use of Statgraphics Centurion XVI.I (2011) statistical software package.

Results and Discussion

As the main evaluation indicators of success of agrotechnical variants of field experiments, we considered the rooting rate and annual height growth of woody plants, the values of which closely depend on both the yield of quality planting material per unit area and the growth energy of introducers.

In a single-factor field experiment to study the effect of mineral fertilizer application doses on the growth and development of seedlings with MC, only *Gleditsia triacanthos* L. took root at 100 % regardless of the variant values (Table 1). “Good” (80–100 %) on average in the field experiment it is estimated in *Ailanthus altissima* (Mill.) Swingle and *Fraxinus lanceolata* Borkh.

Ulmus pumila L., *Armeniaca vulgaris* Lam., *Platycladus orientalis* (L.) Franco and *Ligustrum vulgare* L. took root “satisfactorily” (50–80 %). “Unsatisfactory” (25–50 %) rooting was characterized by *Salix alba f. pendula* and *Populus bolleana* Lauche. that was due to very late planting of cuttings.

The difference between the variants of monthly feeding of plants with mineral complex fertilizer is absent (F_f< F_{05}) only in two tree species with a weak requirement for soil fertility — *Ulmus pumila* L. and *Ailanthus altissima* (Mill.) Swingle. In the other introducers, the difference is significant at 5 % significance level and there is a steady tendency of increasing the value of rooting as the doses of mineral fertilizers increase from 0 to 100 g/m^2. However, the difference between 75 and 100 g/m^2 variants is insignificant or not pronounced at all.

For the two-factor field experiment on the effect of irrigation regime and substrate preparation on seedling growth and development, the highest rooting rate (97.9 %) was also found for *Gleditsia triacanthos* L. (Table 2). "Good", by 80–100 %, took root *Ulmus pumila* L., *Ligustrum vulgare* L. and *Fraxinus lanceolata* Borkh. At *Ailanthus altissima* (Mill.) Swingle, *Armeniaca vulgaris* Lam., *Platycladus orientalis* (L.) Franco is estimated as "satisfactory" (50–80 %). Very low survival rate was observed in cuttings of *Salix alba f. pendula* (17.9 %) and *Populus bolleana* Lauche. (25.0 %).

Most plants showed a stable tendency of increasing the rooting rate with increasing soil moisture and peat percentage, but up to a certain level and with different degree of reliability. For factor A the difference between the variants is reliable (F_f>F_{05}) for *Ulmus pumila* L., *Platycladusorientalis* (L.) Franco, *Ligustrum vulgare* L., *Gleditsia triacanthos* L. and *Fraxinus lanceolata* Borkh. The other species react weakly to the increase in soil moisture and there is no statistically significant difference in rooting (F_f<F_{05}). Woody plants are more responsive to factor B (percentage of peat in the substrate) in terms of rooting. The difference is significant at 5 % significance level for 6 species out of 9: *Ulmus pumila* L., *Salix alba f. pendula*, *Populus bolleana Lauche.*, *Platycladusorientalis* (L.) Franco, *Ligustrum vulgare* L. and *Fraxinus lanceolata* Borkh. (Tab. 2).

Table 1

Adoption rate of woody plants in a one-factor field experiment on the effect of mineral fertilizer application doses on the growth and development of seedlings with CRS (in percent)

Plants	Variant of experiment					
	Norms of monthly fertilization of plants with mineral Kemira "Spring-Summer" complex fertilizer					
	control	25 g/m^2	50 g/m^2	75 g/m^2	100 g/m^2	Average:
Ulmus pumila L.	55	60	60	70	65	62,0
Statistics:	$F_ф$ = 1.13. F_{05} = 3.26. S_x = 5.3. S_d= 7.5. HCP_{05} = 23.8.					
Ailanthus altissima (Mill.) Swingle	95	90	95	95	95	94,0
Statistics:	$F_ф$ = 0.62. F_{05} = 3.26. S_x = 2.8. S_d= 4.0. HCP_{05} = 12.7.					
Armeniaca vulgaris Lam.	60	65	70	80	75	70,0
Statistics:	$F_ф$ = 4.54. F_{05} = 3.26. S_x = 3.7. S_d= 5.2. HCP_{05} = 16.5.					
Salix alba f. pendula	25	40	40	45	60	42,0
Statistics:	$F_ф$ = 7.24. F_{05} = 3.26. S_x = 3.6. S_d= 6.5. HCP_{05} = 20.7.					
Populus bolleana Lauche.	25	25	25	35	55	31,0
Statistics:	$F_ф$ = 13.91. F_{05} = 3.26. S_x = 2.4. S_d= 3.4. HCP_{05} = 10.8.					
Platycladus orientalis (L.) Franco	50	55	55	60	65	57
Statistics:	$F_ф$ = 3.60. F_{05} = 3.26. S_x = 3.4. S_d= 4.9. HCP_{05} = 15.6.					
Ligustrum vulgare L.	60	60	75	75	70	68,0
Statistics:	$F_ф$ = 10.96. F_{05} = 3.26. S_x = 2.6. S_d= 3.7. HCP_{05} = 11.9.					
Gleditsia triacanthos L.	100	100	100	100	100	100,0
Statistics:	$F_ф$ = 0.00. F_{05} = 3.26. S_x = 0.0. S_d= 0.0. HCP_{05} = 0.0.					
Fraxinus lanceolata Borkh.	70	80	80	85	85	80,0
Statistics:	$F_ф$ = 6.80. F_{05} = 3.26. S_x = 3.3. S_d= 4.7. HCP_{05} = 14.9.					
Average:	59,4	65,0	63,3	67,2	69,4	64,8
Statistics:	$F_ф$ = 5.42. F_{05} = 3.26. S_x = 3.0. S_d= 4.4. HCP_{05} = 14.0.					

Note. F_f — actual difference significance criterion; F_{05} — Fisher's criterion at the significance level of 5 %; S_x — generalized mean error; S_d — mean difference error; HCP_{05} — smallest significant difference at the significance level of 5 %.

Table 2

Adoption rate of woody plants in a two-factor field experiment on the influence of irrigation regime and substrate preparation on the growth and development of seedlings with MC (in percent)

Plant, Variant of experiment – Factor A	Variant meaning, % from NV	Variant of experience — factor B				
		Ratio of plant and peat soil in substrate preparation				
		Control	2: 1	1: 1	1: 2	Average
Ulmus pumila L.						
Pre-watering soil moisture	50-60	85	90	85	90	87,5
	60-70	60	75	80	95	77,5
	70-80	80	90	95	100	91,3
Average:		75,0	85,0	86,7	95,0	85,4
Statistics: $F_{\phi A}$ = 44.40. F_{05A} = 3.23. $F_{\phi B}$ = 39.50. F_{05B} = 2.79. S_x = 4.4. S_d = 6.3. HCP_{05} = 12.6.						
Ailanthus altissima (Mill.) Swingle						
Pre-watering soil moisture	50-60	65	60	80	75	70,0
	60-70	75	70	75	70	72,5
	70-80	60	80	85	75	75,0
Average:		66,7	70,0	80,0	73,3	72,5
Statistics: $F_{\phi A}$ = 0.14. F_{05A} = 3.23. $F_{\phi B}$ = 0.17. F_{05B} = 2.79. S_x = 234. S_d = 33.1. HCP_{05} = 66.6.						
Armeniaca vulgaris Lam.						
Pre-watering soil moisture	50-60	70	75	65	100	77,5
	60-70	75	70	70	100	78,8
	70-80	75	80	70	100	81,2
Average:		73,3	75,0	68,3	100,0	79,2
Statistics: $F_{\phi A}$ = 186. F_{05A} = 3.23. $F_{\phi B}$ = 0.17. F_{05B} = 2.79. S_x = 2.3. S_d = 3.2. HCP_{05} = 6.4.						
Salix alba f. pendula						
Pre-watering soil moisture	50-60	0	0	35	45	20,0
	60-70	0	0	40	45	21,2
	70-80	0	0	15	35	12,5
Average:		0,0	0,0	30,0	41,7	17,9
Statistics: $F_{\phi A}$ = 1.83. F_{05A} = 3.23. $F_{\phi B}$ = 11.49. F_{05B} = 2.79. S_x = 7.0. S_d = 9.9. HCP_{05} = 19.9.						
Populus bolleana Lauche.						
Pre-watering soil moisture	50-60	0	45	50	0	23,8
	60-70	0	40	55	0	23,8
	70-80	0	35	75	0	27,5
Average:		0,0	40,0	60,0	0,0	25,0
Statistics: $F_{\phi A}$ = 2.85. F_{05A} = 3.23. $F_{\phi B}$ = 9.57. F_{05B} = 2.79. S_x = 7.0. S_d = 9.9. HCP_{05} = 19.9.						
Platycladus orientalis (L.) Franco						
Pre-watering soil moisture	50-60	55	70	70	95	72,5
	60-70	65	75	80	90	77,5
	70-80	80	85	85	100	87,5
Average:		66,7	76,7	78,3	95,0	79,2
Statistics: $F_{\phi A}$ = 55.90. F_{05A} = 3.23. $F_{\phi B}$ = 187.50. F_{05B} = 2.79. S_x = 1.6. S_d = 2.2. HCP_{05} = 4.4.						
Ligustrum vulgare L.						
Pre-watering soil moisture	50-60	75	85	85	90	83,8
	60-70	65	80	80	90	78,8
	70-80	80	90	90	100	90,0
Average:		73,3	85,0	85,0	93,3	84,2
Statistics: $F_{\phi A}$ = 19.56. F_{05A} = 3.23. $F_{\phi B}$ = 46.81. F_{05B} = 2.79. S_x = 3.6. S_d = 5.1. HCP_{05} = 10.2.						

Continuation of Table 2

Plant, Variant of experiment – Factor A	Variant meaning, % from NV	Variant of experience — factor B				
		Ratio of plant and peat soil in substrate preparation				
		Control	2: 1	1: 1	1: 2	Average
Gleditsia triacanthos L.						
Pre-watering soil moisture	50-60	100	95	95	95	96,2
	60-70	95	95	100	100	97,5
	70-80	100	100	100	100	100,0
Average:		98,3	96,7	98,3	98,3	97,9
Statistics: $F_{\phi A} = 4.10$. $F_{05A} = 3.23$. $F_{\phi B} = 0.57$. $F_{05B} = 2.79$. $S_x = 1.9$. $S_d = 2.6$. $HCP_{05} = 5.2$.						

The value of rooting rate in nursery practice depends very much on the quality of planting material and observance of optimal planting dates. Therefore, its correlation coefficients with the rate of monthly feeding of plants with mineral complex fertilizer, pre-watering soil moisture and peat-soil content in the substrate do not look as convincing as expected, respectively — 0.49; 0.27 and 0.60 (Table 3), which is associated with the relatively cool and wet summer period of recent years. The same reason can be explained by too complicated derived formulaic relationships of rooting percentage with agrotechnical parameters — exponential, steppe and multiplicative types.

Table 3

Correlation of woody plant establishment with pre-watering soil moisture, peat-soil content in soil substrate and rate of monthly feeding with mineral complex fertilizer

Plants	Pre-watering soil moisture		The content of peat in the soil substrate		Feeding rate mineral fertilizer	
	Coefficient					
	Correlation	Determination	Correlation	Determination	Correlation	Determination
Ulmus pumila L.	0.41	0.17	0.47	0.22	0.51	0.26
Ailanthus altissima (Mill.) Swingle	0.14	0.02	0.14	0.02	0.33	0.11
Armeniaca vulgaris Lam.	0.01	0.00	0.92	0.85	0.76	0.57
Salix alba f. pendula	0.22	0.05	0.67	0.45	0.22	0.05
Populus bolleana Lauche.	026	0.07	0.62	0.38	0.90	0.81
Platycladus orientalis (L.) Franco	046	0.21	0.80	0.64	0.62	0.38
Ligustrum vulgare L.	043	0.18	0.67	0.45	0.45	0.20
Gleditsia triacanthos L.	0.39	0.15	0.17	0.03	0.00	0.00
Fraxinus lanceolata Borkh.	0.14	0.02	0.91	0.83	0.61	0.38
Average:	0.27	0.07	0.60	0.36	0.49	0.24
Critical value of the correlation coefficient at the significance level of 5 %	0.27	-	0.27	-	0.44	-

Judging by the graphical representation of the derived regression equations, the increase in rooting rate with the growth of the selected agrotechnical factors is clearly visible. However, at detailed analysis of research materials it can be stated that the most preferable for its value are the following variants of field experiments: maintenance of pre-watering level of soil moisture within 70–80 % of CM, mixing of vegetable and peat soil in the ratio of 1: 1 and monthly feeding with mineral complex fertilizer at the rate of 75 g/m^2.

According to the value of height increment, the difference between the variants in the single-factor field experiment is significant at 5 % significance ($F_f > F_{05}$) for all species of woody plants (Table 4). According to the reaction of height increment to the increase in doses of mineral fertilizer feeding, the introducers are divided into two types:

- "increasing" (from 0 to 100 g/m^2) — *Ailanthus altissima* (Mill.) Swingle, *Armeniaca vulgaris* Lam., *Salix alba f. pendula*, *Populus bolleana* Lauche., *Ligustrum vulgare* L., *Gleditsia triacanthos* L.; and
- "variable" (with a maximum at the variant 75 g/m^2) — *Ulmus pumila* L., *Platycladus orientalis* (L.) Franco and *Fraxinus lanceolata* Borkh.

Table 4

Height increment of woody plants in a one-factor field experiment on studying the effect of mineral fertilizer application doses on the growth and development of Seedlings with CRS (in cm)

Plants	Variant of experiment					
	Norms of monthly fertilization of plants with mineral Kemira "Spring-Summer" complex fertilizer					
	control	control	control	control	control	control
Ulmus pumila L.	18.5	30.4	27.3	41.2	39.9	31.5
Statistics:	$F_ф = 350.00$. $F_{05} = 3.26$. $S_x = 1.6$. $S_d = 2.2$. $HCP_{05} = 7.0$.					
Ailanthus altissima (Mill.) Swingle	9.0	10.4	13.3	14.7	15.9	12.7
Statistics:	$F_ф = 45.00$. $F_{05} = 3.26$. $S_x = 1.1$. $S_d = 1.6$. $HCP_{05} = 5.1$.					
Armeniaca vulgaris Lam.	3.0	15.0	23.0	23.9	30.9	19.2
Statistics:	$F_ф = 113.75$. $F_{05} = 3.26$. $S_x = 1.0$. $S_d = 1.4$. $HCP_{05} = 4.5$.					
Salix alba f. pendula	39.7	65.4	68.1	90.5	100.8	72.9
Statistics:	$F_ф = 27.52$. $F_{05} = 3.26$. $S_x = 4.1$. $S_d = 5.8$. $HCP_{05} = 18.4$.					
Populus bolleana Lauche.	9.0	23.9	47.9	45.4	46.0	34.4
Statistics:	$F_ф = 26.60$. $F_{05} = 3.26$. $S_x = 3.2$. $S_d = 4.5$. $HCP_{05} = 14.2$.					
Platycladus orientalis (L.) Franco	10.4	10.4	11.8	20.4	20.0	14.6
Statistics:	$F_ф = 21.62$. $F_{05} = 3.26$. $S_x = 1.4$. $S_d = 2.0$. $HCP_{05} = 6.4$.					
Ligustrum vulgare L.	7.9	15.7	29.0	30.0	38.1	24.1
Statistics:	$F_ф = 10.78$. $F_{05} = 3.26$. $S_x = 2.8$. $S_d = 3.9$. $HCP_{05} = 12.4$.					
Gleditsia triacanthos L.	20.9	26.2	31.4	40.5	45.2	32.8
Statistics:	$F_ф = 6.32$. $F_{05} = 3.26$. $S_x = 3.2$. $S_d = 4.5$. $HCP_{05} = 14.2$.					
Fraxinus lanceolata Borkh.	15.5	15.4	15.2	18.8	18.6	16.7
Statistics:	$F_ф = 4.67$. $F_{05} = 3.26$. $S_x = 0.9$. $S_d = 1.2$. $HCP_{05} = 3.8$.					
Average:	14.9	23.6	29.7	36.2	39.5	28.8
Statistics:	$F_ф = 6.74$. $F_{05} = 3.26$. $S_x = 2.1$. $S_d = 3.0$. $HCP_{05} = 9.5$.					

In the two-factor experiment, the combination of soil moisture and the percentage of peat in the substrate also had a statistically significant effect on the growth of the overwhelming majority of taxa, except for *Armeniaca vulgaris* Lam. (factors A and B) and *Populus bolleana* Lauche (factor B). However, different variants are optimal for their growth vigor (Table 5):

- For *Ulmus pumila* L. (29.7 cm), *Salix alba f. pendula* (66.4 cm) — pre-watering moisture threshold of 60–70 % of MC and ratio of ratite and peat soil in the substrate 1: 1;
- *Ailanthus altissima* (Mill.) Swingle (26.9 cm) and *Gleditsia triacanthos* L. — 70–80 and 1: 2, respectively;
- *Ligustrum vulgare* L. (23.3 cm) and *Fraxinus lanceolata* Borkh. (42.8 cm) — 60–70 and 1: 2;
- *Armeniaca vulgaris* Lam. (20.9 cm), *Platycladus orientalis* (L.) Franco (21.7 cm) and *Populus bolleana* Lauche. (40.7 cm) — 70–80 and 1: 1.

Annual height growth is characterized by a more pronounced variation (up to 47.7–94.1 %) in the variants of the experiment compared to the rooting rate, and its dependence on agrotechnical variants looks much tighter. Thus, if the correlation coefficient of rooting percentage with the rate of monthly feeding of woody plants with mineral complex fertilizer is 0.49, pre-watering soil moisture — 0.27 and the content of peat in the soil substrate — 0.60, then the height increment — respectively: 0.84; 0.35 and 0.62 (Table 6). These agrotechnical factors, judging by the value of the coefficient of determination, determine up to 69–95 % of all changes in growth energy by height.

Table 5

Height increment of woody plants in a two-factor field experiment on the influence of irrigation regime and substrate preparation on the growth of seedlings of CRS (in centimeters)

Plant, variant of experiment – factor A	Variant values, %	Variants of experiments — factor B				
		Ratio of plant and peat soil for substrate preparation				
		Control	2: 1	1: 1	1: 2	Average
Ulmus pumila L.						
Pre-irrigation soil humidity	50-60	15.5	13.5	19.7	16.7	16.4
	60-70	20.4	29.3	29.7	25.0	26.1
	70-80	11.4	11.7	19.7	16.9	14.9
Average:		15.8	18.2	23.0	19.5	19.1
Statistics: $F_{фA}$ = 197.00. F_{05A} = 3.23. $F_{фB}$ = 36.67. F_{05B} = 2.79. S_x = 0.8. S_d = 1.2. HCP_{05} = 2.4.						
Ailanthus altissima (Mill.) Swingle						
Pre-irrigation soil humidity	50-60	11.2	11.1	17.1	18.6	14.5
	60-70	11.9	7.3	17.9	20.7	14.5
	70-80	13.6	12.7	17.9	26.9	17.8
Average:		12.2	10.4	17.6	22.1	15.6
Statistics: $F_{фA}$ = 3.47. F_{05A} = 3.23. $F_{фB}$ = 22.27. F_{05B} = 2.79. S_x = 1.9. S_d = 2.7. HCP_{05} = 5.4.						
Armeniaca vulgaris Lam.						
Pre-irrigation soil humidity	50-60	9.8	9.4	18.3	16.0	13.4
	60-70	3.8	8.8	14.5	10.8	9.5
	70-80	6.1	10.6	20.9	15.3	13.2
Average:		6.6	9.6	17.9	14.0	12.0
Statistics: $F_{фA}$ = 1.86. F_{05A} = 3.23. $F_{фB}$ = 0.17. F_{05B} = 2.79. S_x = 2.3. S_d = 3.2. HCP_{05} = 6.4.						
Salix alba f. pendula						
Pre-irrigation soil humidity	50-60	-	-	24.4	63.8	44.1
	60-70	-	-	33.5	65.6	49.6
	70-80	-	-	31.5	66.4	49.0
Average:		-	-	29.8	65.3	47.5
Statistics: $F_{фA}$ = 449.26. F_{05A} =3.23. $F_{фB}$ = 309.84. F_{05B} = 2.79. S_x = 2.1. S_d = 3.1. HCP_{05} = 6.2.						
Populus bolleana Lauche.						
Pre-irrigation soil humidity	50-60	-	31.4	37.9	-	34.7
	60-70	-	34.3	37.7	-	36.0
	70-80	-	33.9	46.6	-	40.3
Average:		-	33.2	40.7	-	37.0
Statistics: $F_{фA}$ = 5.38. F_{05A} = 3.23. $F_{фB}$ = 1.19. F_{05B} = 2.79. S_x = 15.2. S_d = 21.6. HCP_{05} = 43.4.						
Platycladusorientalis (L.) Franco						
Pre-irrigation soil humidity	50-60	9.1	12.5	8.7	12.4	10.7
	60-70	9.7	12.7	12.1	14.1	12.2
	70-80	19.1	12.2	21.7	16.5	15.9
Average:		10.6	12.5	14.2	14.3	12.9
Statistics: $F_{фA}$ = 48.00. F_{05A} = 3.23. $F_{фB}$ = 21.60. F_{05B} = 2.79. S_x = 1.1. S_d = 1.6. HCP_{05} = 3.2.						
Ligustrum vulgare L.						
Pre-irrigation soil humidity	50-60	6.0	10.7	14.0	14.8	11.4
	60-70	11.1	13.8	30.5	42.8	24.6
	70-80	11.2	13.9	33.1	36.3	23.6
Statistics: $F_{фA}$ = 432.50. F_{05A} = 3.23. $F_{фB}$ = 651.00. F_{05B} = 2.79. S_x = 0.7. S_d = 1.0. HCP_{05} = 2.0.						
Average:		9.4	12.8	25.9	31.3	19.9
Gleditsia triacanthos L.						
Pre-irrigation soil humidity	50-60	18.5	26.7	28.8	41.9	29.0
	60-70	15.6	19.3	27.8	58.6	30.3
	70-80	19.7	23.3	30.0	69.2	35.6
Average:		17.9	23.1	28.9	56.6	31.6
Statistics: $F_{фA}$ = 299.20. F_{05A} = 3.23. $F_{фB}$ = 284.33. F_{05B} = 2.79. S_x = 1.5. S_d = 2.1. HCP_{05} = 4.2.						

Continuation of Table 5

Plant, variant of experiment – factor A	Variant values, %	Variants of experiments — factor B				
		Ratio of plant and peat soil for substrate preparation				
		Control	2: 1	1: 1	1: 2	Average
Fraxinus lanceolata Borkh.						
Pre-irrigation soil humidity	50-60	2.2	20.8	15.0	16.0	13.5
	60-70	2.1	16.1	15.7	25.4	14.8
	70-80	5.5	18.8	19.6	23.3	16.8
Average:		3.3	18.6	16.8	21.6	15.0
Statistics: $F_{фA}$ = 3.38. F_{05A} = 3.23. $F_{фB}$ = 60.54. F_{05B} = 279. S_x = 1.8. S_d = 2.5. HCP_{05} = 5.0.						
Average for all plant species:		10.8	17.3	23.9	30.6	20.6
Statistics: $F_{фA}$ = 44.40. F_{05A} = 3.23. $F_{фB}$ = 39.50. F_{05B} = 2.79. S_x = 4.4. S_d = 6.3. HCP_{05} = 126.						

Table 6

Correlation of height increment of woody plants with pre-watering soil moisture, peat-soil content in soil substrate and rate of monthly feeding with mineral complex fertilizer

Plants	Pre-irrigation soil humidity		The content of peat in the soil substrate		Rate of fertilization with mineral fertilizer	
	Coefficient					
	Correlation	Determination	Correlation	Determination	Correlation	Determination
Ulmus pumila L.	0.81	0.66	0.43	0.18	0.97	0.94
Ailanthus altissima (Mill.) Swingle	0.24	0.06	0.75	0.56	0.79	0.62
Armeniaca vulgaris Lam.	0.10	0.01	0.92	0.85	0.97	0.94
Salix alba f. pendula	0.69	0.48	0.71	0.50	0.90	0.81
Populus bolleana Lauche.	0.45	0.20	0.37	0.12	0.94	0.88
Platycladus orientalis (L.) Franco	0.77	0.59	0.36	0.13	0.80	0.64
Ligustrum vulgare L.	0.51	0.26	0.77	0.59	0.74	0.55
Gleditsia triacanthos L.	0,.52	0.27	0.38	0.14	0.81	0.66
Fraxinus lanceolata Borkh.	0.17	0.03	0.87	0.76	0.63	0.40
Average:	0.35	0.12	0.62	0.38	0.84	0.70
Critical value of the correlation coefficient at the significance level 5 %	0.27	-	0.27	-	0.44	-

The graphs constructed according to the derived formulas on the data averaged for all experimental plants reflect only a general trend of growth increase with increasing values of the selected agrotechnical parameters. At the same time, taking into account the need to save organic and mineral fertilizers, we conclude that the most favorable conditions for the growth of introducers in height are created by combining such variants of field experiments as: mixing vegetable and peat soil in the ratio of 1:1, monthly feeding with mineral complex fertilizer at the rate of 75 g/m^2 and maintaining pre-watering threshold of soil moisture — 70–80 % of MC.

Leaf plate size and physiological parameters of growth and development were studied as additional indicators to rooting and height increment in order to reveal regularities of woody plants reaction to changing habitat conditions under the influence of artificially created agrotechnical factors depending on their biological properties and needs and adaptive qualities.

In principle, the extreme variant values of soil moisture and fertilizer application doses for the experimental taxa are within the limits of habitual growing conditions, but they should be strongly manifested on their habitus and morphophysiological characteristics. However, in both one- and two-factor field experiments, the relationship between the variants in terms of leaf size, weight, and area generally follows the same pattern as the difference in height increment, but in a less pronounced manner. With increasing percentage of peat-soil in the substrate and norms of mineral fertilizers application, there is only a tendency to increase all leaf parameters, and low soil moisture leads to the development of its xeromorphic structure.

The raw weight of leaf lamina was chosen as an integral indicator of leaf morphology of woody plants. Among the experimental species, the correlation (r = 0.89-0.93) of weight dependence with the dose of mineral fertilizer application was confirmed only in three species: *Ailanthus altissima* (Mill.) Swingle, *Salix alba f. pendula*, *Populus bolleana* Lauche. and *Ligustrum vulgare* L. In other taxa, the relationship with this agronomic factor is not significant at 5 %, especially in common apricots (r = -0,40).

In the two-factor field experiment, the correlation of leaf weight with pre-watering soil moisture is statistically reliable (r = 0.94) only in *Populus bolleana* Lauche. as a moisture-loving species; with the content of peat in the soil substrate — *Ailanthus altissima* (Mill.) Swingle, *Armeniaca vulgaris* Lam., *Salix alba f. pendula* и *Ligustrum vulgare* L. (r = 0,94).

Among physiological indicators of woody plants, transpiration is one of the main ones from the point of view of habitat improvement in the Mangistau desert. The issue of physiological water yield is also relevant because in conditions of soil moisture limit, the process of maximizing plant productivity is reduced to simultaneous optimization of solar radiation absorption and water consumption through transpiration. Moreover, transpiration is an integral physiological process of plant organism and is extremely necessary for its vital activity as a protective mechanism against leaf overheating under direct exposure to sunlight, as a creator of continuous flow of water and mineral nutrients from the root system to other anatomical organs.

In our experiments, according to the average values of transpiration intensity (TI), all introducers were divided into two groups: weakly transpiring (less than 200 mg/g of raw leaf weight per hour) — *Platycladus orientalis* (L.) Franco; medium-transpiring (200–500 mg/g of raw leaf weight per hour) — *Ulmus pumila* L., *Salix alba f. pendula*, *Ligustrum vulgare* L., and *Fraxinus lanceolata* Borkh.

Since transpiration is the final stage of irrigation water cycle in soil and plant, its conjugation with soil moisture and closely related leaf water content is undoubted even from the logical point of view. This has been experimentally confirmed by a number of authors [12–15]. With decreasing soil moisture, the level of transpiration decreases. The less water in the soil, the weaker the water supply of the plant. Reduction of water content in the plant organism automatically reduces the transpiration process due to the auricular and extraauricular regulation.

According to the data of correlation analysis, soil moisture determines only 22.0 % of changes in transpiration intensity (r = 0.39), which is less than expected and is primarily due to its dependence on other factors, especially meteorological (light intensity, relative humidity and air temperature, wind speed, etc.). Moreover, for different woody plants the correlation coefficient varies in very wide ranges — from 0.15 to 0.88. Its maximum value was recorded for the tree of mesophytic series — *Salix alba f. pendula*. The closeness of TI correlation with the rate of monthly feeding with mineral fertilizer (r = 0.15) and the content of peat-soil in the substrate (r = -0.11) is even lower, and its change with the growth of these factors is practically inconsistent with the data on plant height increment.

In the process of research, the content of chlorophyll in leaves, which is the most important component of their photosynthetic apparatus, was also determined. The relationship between photosynthesis and water regime is mainly due to the influence that water has on the whole complex of processes of plant organism vital activity. It is noted, in particular, suppression or enhancement of synthesis of green pigments. Preservation of plant viability under water deficiency is closely related to the functioning of pigment systems. The determining factor affecting the pigment complex of leaves is water availability. Plants with high drought tolerance lose less water and their chlorophyll is more stable [16]. Considering that protein substances play a major role in the development of water-holding capacity of tissues and that a significant part of proteins, especially soluble proteins, is concentrated in chloroplasts, we can assume the influence of chlorophyll content on water-holding capacity and its relationship with lipoprotein complexes [17].

According to the materials of our studies, the change in chlorophyll content in leaves with the growth of variant values of mineral fertilizer rates, soil moisture and the ratio of vegetable and peat soil in the substrate almost completely coincides with the growth in height. Thus, in the single-factor experiment, when increasing fertilizer rates from 0 to 100 g/m^2, the percentage of chorophyll per raw leaf weight increases from 0.47 to 0.66 on average. Increasing the pre-watering threshold of soil moisture from 50–60 to 70–80 % of MC in the two-factor experiment is accompanied by an increase in the content of this pigment from 0.49 to 0.55-0.70, and the percentage of peat in the substrate from 0 to 67 (1: 2) — from 0.53 to 0.63 %. It is interesting to note that coniferous trees are more saturated with chlorophyll (0.70 %) compared to deciduous trees (0.50-0.58 %) regardless of the values of agrotechnical factors.

Judging by the results of correlation analysis, chlorophyll formation is more significantly influenced by the improvement of soil nutrient regime through the application of complex mineral fertilizers than by the irrigation regime and the method of substrate preparation. The correlation coefficient of its content with these factors is, respectively, 0.78; 0.45 and 0.45. The chlorophyll content of *Salix alba f.* pendula is most closely related to the rate of fertilization (r=0.94) and *Ligustrum vulgare* L. (0.95), with pre-watering humidity — *Ulmus pumila* L. (0.75), *Salix alba f. pendula*(0.76) and *Platycladus orientalis* (L.) Franco (0.53) and with the percentage of peat in the substrate — *Ulmus pumila* L. (0.56), *Salix alba f. Pendula* (0.58) and *Ligustrum vulgare* L. (0.68).

For both field experiments, we also calculated correlation and determination coefficients of height increment, as the main indicator of success of growing conditioned planting material, with transpiration rate and chlorophyll content. Due to high variability and strong dependence on meteorological factors, the correlation of transpiration intensity with the value of growth is generally unreliable at the 5 % level of significance (r=0.11-0.18), and chlorophyll content, on the contrary, is at a fairly high level (r=0.61-0.79). Thus, the saturation of leaves with this pigment is a rather reliable physiological indicator of successful growth and development of plants with CRS.

Due to sufficiently high correlation of chlorophyll content (CHL) with agrotechnical factors, it was possible to derive reliable by significance regression equations of exponential and multiplicative type averaged for the whole group of experimental plants. The formula relationship between CHL and mineral fertilizer application rates is characterized by a gradual increase in the dependent variable up to the rate of mineral fertilizer application 35–40 g/m^2, then its value begins to increase rapidly and reaches at 100 g/m^{2-} 0.70 %. The dependence of CHL and pre-watering soil moisture is close to linear in appearance, but a little bent at the value of soil moisture 65 % of MC. According to the graph of the relationship between CHL and the content of peat in the soil substrate clearly shows that a sharp increase in the first parameter occurs when changing the second in the range from 50 to 80 %, but still in percentage terms, the content of chlorophyll changes here insignificantly — no more than 0.04 %.

It should be noted that in recent years, to study the effectiveness of the use of various moisture-retaining materials in the cultivation of seedlings with a closed root system in the container nursery, another one-factor field experiment was also laid in 5 variants: 1) control (without shelter); 2) Zeba super-sorbent; 3) gravel; 4) sewage treatment plant sludge and 5) sawdust with the involvement of 10 species and forms of woody plants: *Platycladus orientalis* (L.) Franco, *Ulmus pumila* L., *Ailanthus altissima* (Mill.) Swingle, *Armeniaca vulgaris* Lam., *Gleditsia triacanthos* L., *Salix alba f. pendula*, *Morus alba* L., *Sophora japonica* L., *Salix alba f. piramidalis* and *Ligustrum vulgare* L.

Due to the autonomy of the root system in the presence of a container, localization of irrigation and differences in bioecological properties, the selected woody plants reacted differently to the type of water retention material used. At the same time, the general trend is that they take root better in the Zeba option, and grow faster in height when covered with sewage sludge due to additional supply of nutrients. The greatest water saving occurs when sawdust is used — 77.8 % (about 5000 m^3/ha) and almost equally — sludge and gravel 83.5–84.4 % (3000–3200 m^3/ha).

According to the conducted evaluation of economic efficiency, the incurred costs for all variants of the field experiment are recouped in one period of vegetation, but with a significant difference in profitability between the use of super-sorbent Zeb (5.7 %) and other types of sheltering materials. The best economic indicators have the use of sawdust (46.6 %) and sludge (41.9 %).

Conclusion

Thus, based on the analysis of the obtained research material it was concluded that the following agrotechnical practices are the most preferable in terms of biometric and physiological indicators of growth and development of woody plants: 1) — maintenance of pre-watering level of soil moisture within 70–80 % of NV, 2) — mixing of vegetable and peat soil in the ratio of 1: 1 and 3) — monthly feeding with mineral complex fertilizer at the rate of 75 g/m^2.The most effective in the conditions of the Mangistau desert to prevent evaporation of moisture under green plantations are such covering materials as Zeb super-sorbenta, sludge of sewage treatment plants and gravel of medium and fine fractions.

In recent years, the results of research have been successfully tested in the mass propagation of 107 species, forms and varieties of the most promising introducers from 32 genera and 17 families (a total of 65340 containers). In general, the creation of the first specialized nursery in the region on the basis of the MEBG with the application of scientifically sound cultivation technology will contribute to meeting the needs of horticultural and landscaping organizations in seedlings and seedlings of high quality and a wide range of assortment to solve, ultimately, the problems of increasing the productivity of horticultural and landscaping organizations.

Acknowledgements

The research was carried out within the framework of the program BR21882166 “Scientific and practical bases of reproduction, conservation, utilization of fruit and berry plants of natural flora of Western, Eastern, Central and Northern Kazakhstan to ensure food security” (2023–2025).

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Ауылшаруашылығын өсіру технологиясын оңтайландырудың негізгі бағыттары жабық тамыр жүйесі бар ағаш өсімдіктерінің көшеттері Маңғыстау шөлінің құрғақ жағдайында

Зерттеу жұмысының мақсаты — Маңғыстаудың құрғақ жағдайында жабық тамыр жүйесі бар ағаш өсімдіктерінің көшеттерін өсіру агротехникасының далалық тәжірибелерін отырғызу арқылы оңтайландыру. Жиналған зерттеу материалының дисперсиялық және корреляциялық талдауы негізінде келесі агротехникалық әдістер ағаш өсімдіктерінің өсуі мен дамуының биометриялық және физиологиялық көрсеткіштері бойынша ең қолайлы деген қорытынды жасалған: 1) топырақ ылғалдылығының алдын-ала деңгейін толық далалық ылғал сыйымдылығының 70-80% шегінде ұстап тұру, 2) 1:1 қатынасында өсімдік пен шымтезек топырағын араластыру және 3) 75 г/м^2 мөлшерінде минералды кешенді тыңайтқышпен ай сайын құнарландыру. Маңғыстау шөлі жағдайында жасыл желектер астындағы ылғалдың булануын болдырмау үшін ең тиімдісі Зеб суперсорбентін, тазарту қондырғыларын орнату және орта және ұсақ фракциялардың қиыршық тастары сияқты жабын материалдары. Зерттеу нәтижелері 32 тұқымдас және 17 туыстың (барлығы 65 340 контейнер) ең перспективалы интродукциялық өсімдіктердің 107 түрін, формалары мен сорттарын жаппай көбейту кезінде сәтті сынақтан өтті.

Кілт сөздер: оңтайландыру, ауылшаруашылық технологиясы, ағаш өсімдіктер, көшеттер, контейнерлер, егістік тәжірибесі, тіршілік ету деңгейі, өсу.

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Основные направления оптимизации агротехники выращивания саженцев древесных растений с закрытой корневой системой в аридных условиях пустыни Мангистау

Цель настоящего исследования — оптимизация путем закладки полевых опытов агротехники выращивания саженцев древесных растений с закрытой корневой системой в аридных условиях Мангистау. На основе дисперсионного и корреляционного анализа собранного исследовательского материала сделан вывод о том, что наиболее предпочтительными по биометрическим и физиологическим показателям роста и развития древесных растений являются следующие агротехнические приемы: 1) поддерживание предполивного уровня почвенной влажности в пределах 70–80 % от полной полевой влагоемкости; 2) смешивание растительного и торфяного грунта в соотношении 1: 1 и 3) ежемесячная подкормка минеральным комплексным удобрением из расчета 75 г/м^2. Самыми эффективными в условиях пустыни Мангистау для предотвращения испарения влаги под зелеными насаждениями являются такие укрывные материалы, как суперсорбент Зеба, осадок очистных сооружений и гравий средней и мелкой фракции. Результаты исследований были успешно апробированы при проведении массового размножения 107 видов, форм и сортов наиболее перспективных интродуцентов из 32 родов и 17 семейств (всего 65340 контейнеров).

Ключевые слова: оптимизация, агротехника, древесные растения, саженцы, контейнеры, полевой опыт, приживаемость, прирост.

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