

Article

Introduction of Kyzylkum Halophytes and Xerophytes on Degraded Soils of The Dried Aral Sea Bed

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Abstract: The paper describes the species composition and seed ripening periods of halophytes and xerophytes growing on the bed of a dried salt lake in Tamdy district, Navoi region, the collection of seeds of 13 species in 2025, and the results of their sowing on 21 February 2026 at the research station on the dried Aral Sea bed. Most species emerged well in spring; however, after the dry and hot summer of 2026, only *Halopeplis perfoliata*, *Salicornia perennans* and *Kochia iranica* had survived by August. Extreme substrate salinity, moisture deficit, drifting sand and harsh temperature conditions are shown to be the main causes of poor establishment. To improve soil fertility and moisture at the sowing site, the agrochemical properties of bentonite, vermiculite, glauconite, sapropel, vermicompost, phosphorite waste and poultry manure were evaluated.

Keywords: Aral Sea, Aralkum, Introduction, Halophyte, Xerophyte, Seed Germination, Phenology, *Halopeplis perfoliata*, *Salicornia perennans*, Organo-Mineral Composition, Phytomelioration

Introduction

The Aralkum is the youngest desert in the world, approximately 60 years old [1], [2]. The exposed seabed is almost devoid of vegetation, and its surface is covered with a layer composed of a mixture of sea sand, salt and shells. The content of sodium bicarbonate, chloride and sulfate in the sand reaches 520 kg per hectare [3]. The present-day flora of the dried bed has been forming since 1960; its main representatives are *Salicornia europaea* and *Suaeda crassifolia* on clay soils and *Suaeda acuminata* and *Atriplex fominii* on sandy soils.

Halophytes are recognized as an important resource for the biological reclamation of saline lands and as a source of forage and medicinal raw materials [4][5][6]. They adapt to salinity by accumulating salts in vacuoles, excreting them through glands or retaining them in the roots. Halophyte farming simultaneously addresses freshwater saving, restoration of soil fertility and

agricultural production. *Climacoptera lanata* yields 10–17 c/ha of dry matter without irrigation and is recommended for the biological melioration of saline lands [7].

Sowing on the dried seabed requires seeds of species adapted to local conditions. The dried salt lake in Tamdy district (Central Kyzylkum) was selected as a model site because its soil salinity is close to that of the Aral Sea bed. The aim of this study was to collect seeds of drought- and salt-tolerant species growing at this lake, to introduce them onto the dried Aral Sea bed and to obtain baseline data for developing a sowing agrotechnology.

Materials and Methods

Field studies were carried out on the bed and shores of a dried salt lake in Tamdy district, Navoi region (40°49'59" N, 64°52'52" E), using the route method combined with semi-stationary observations. The floristic composition was determined using an identification key to higher plants [8]. Seed-collecting expeditions were conducted on 25 September, 9 October, 1 November and 12 December 2025. In total, 10 field trips were made during the project: 7 to Tamdy district and 3 to the research station ("zero point") on the dried Aral Sea bed.

The collected seeds were sown on 21 February 2026 on a plot allocated at the research station. Emergence was assessed from photographs taken on 23 April, and surviving plants were counted on site on 12 August. In the raw materials intended for use at the sowing site, the following parameters were determined: pH, organic matter (loss on ignition), organic carbon (Tyurin method), total nitrogen (Kjeldahl method), mobile phosphorus and exchangeable potassium (Kirsanov method modified by CINA0 [9]), humic and fulvic acids, and water-soluble organic acids.

Results and Discussion

On the bed and margins of the lake, *Halocnemum strobilaceum*, *Halostachys belangeriana*, *Halopeplis perfoliata*, *Salicornia perennans*, *S. borysthenaica*, *S. europaea*, *Climacoptera lanata*, *Halogeton glomeratus*, *Anabasis truncata*, *Aeluropus lagopoides*, *A. littoralis*, *Karelinia caspia* and other species were recorded. Comparison with published data [10],[11] showed that the halophytes and xerophytes of the Central Kyzylkum, apart from some succulents, are almost identical to those of Karakalpakstan.

Seeds of different species do not ripen simultaneously; therefore, collection was carried out in several stages (Table 1).

Table 1. Plant species whose seeds were collected at the dried salt lake in Tamdy

Group	Species	Ripening period	Seeds collected
Chenopodiaceae	<i>Halopeplis perfoliata</i>	September	+++
Perennial grasses	<i>Aeluropus lagopoides</i>	September–October	+++
	<i>Aeluropus littoralis</i>	September–October	+
Succulents	<i>Salicornia borysthenaica</i>	October–November	+
	<i>Salicornia perennans</i>	October–November	+
	<i>Allenrolfea occidentalis</i>	October–November	+
	<i>Anabasis truncata</i>	October–November	+
Sand-binding saltworts	<i>Halocnemum strobilaceum</i>	November–December	+
	<i>Halostachys belangeriana</i>	December	+
	<i>Salicornia tegetaria</i>	December	+
Halophytes and xerophytes	<i>Climacoptera lanata</i>	November–December	+++
	<i>Karelinia caspia</i>	November–December	+++

Note: + – small amount, +++ – large amount of seeds collected.

The largest amount of seeds was obtained from *H. perfoliata*, followed by *A. lagopoides*. Large quantities of *C. lanata* and *K. caspia* seeds were also collected; both species also occur on the Aral Sea bed. *H. strobilaceum*, *H. belangeriana* and *S. tegetaria* occurred as single individuals, and their seeds ripened in December after frosts. Another reason for the small seed yield of these species is that sheep and camels graze the ripe dry shoots. In December, mass germination of shed halophyte seeds was observed as hygroscopic moisture at the soil surface increased.

Climatic conditions and phenology

The climates of the Kyzylkum and the Aralkum are sharply continental and extremely dry, yet they differ from each other (Table 2).

Table 2. Soil and climatic conditions of the Kyzylkum and Aralkum deserts

Feature	Kyzylkum	Aralkum
Winter temperature	milder (mean down to -6°C)	very cold (mean down to -13°C)
Summer temperature	extremely hot (often above $+36^{\circ}\text{C}$)	hot, slightly cooler (about $+31^{\circ}\text{C}$)
Surface type	sand and ancient rocks	solonchaks and former seabed
Main hazard	ordinary drought	dust storms carrying salt and chemicals

Mean annual precipitation in the Aralkum is 120–150 mm, most of which falls in winter and early spring, while potential evaporation exceeds precipitation several-fold. In July–August, air temperature rises to $+45^{\circ}\text{C}$ and on some days to $+49^{\circ}\text{C}$. Under these conditions, most halophytes cease growth in summer, and only the deep-rooted *K. caspia*, *A. lagopoides* and the most tolerant hyperhalophytes continue to grow. Based on these observations, late autumn and early spring were identified as the most favourable sowing periods.

The summer of 2026 was considerably drier and hotter than the previous one. Whereas on 12 December 2025 more than 200,000 m³ of groundwater-fed water had accumulated in Tamdy lake, by 14 September 2026 the water had evaporated completely, leaving a solonchak. Many plants on the lake bed grew to only 12–15 cm and dried out without setting seed.

Results of introduction on the dried Aral Sea bed

Photographs taken on 23 April showed uniform emergence of *K. caspia*, *A. lagopoides* and species of the family Chenopodiaceae. The spring was wet throughout Uzbekistan. However, the count on 12 August gave a different result (Table 3).

Table 3. Emergence and survival of species sown on the dried Aral Sea bed (2026)

Species	Spring emergence	Status on 12 August
<i>Halopeplis perfoliata</i>	present	4 small, poorly developed plants
<i>Aeluropus lagopoides</i>	abundant (May)	all dried out
<i>Aeluropus littoralis</i>	abundant (May)	all dried out
<i>Salicornia perennans</i>	present	single, normally developed plants; seed set expected
<i>Kochia iranica</i>	present	1 weak plant
Other species	uniform	all dried out

Thus, only three of the sown species survived until the end of summer. Of these, *S. perennans* was in the best condition and is expected to set seed. In October 2025, local stands of *C. lanata* and *K. caspia* had been recorded along the road to the station, but they were absent in August 2026. This further confirms that the summer was exceptionally dry.

Although Kyzylkum species are evolutionarily adapted to harsh conditions, on the exposed seabed they are affected by several adverse factors simultaneously [12]. A dense salt crust consisting of sodium chloride, sulfate and bicarbonate has formed on the surface. Its high osmotic pressure prevents water uptake by the seeds, so that they either fail to germinate or die. The soil may also contain residues of pesticides and fertilizers washed for decades from cotton fields in the Amu Darya and Syr Darya basins [13]. The main limiting factor, however, is moisture deficit: the groundwater table has dropped, the upper layer dries out almost instantly, and seeds cannot obtain the initial moisture needed for imbibition [14]. In summer, the surface of dark solonchak or sand heats up to +50 °C and above, while in winter the unprotected soil freezes deeply. Constant strong winds blow the seeds away or bury them under drifting sand [15]. A clear example is the road 400 m from the station, which has been buried by sand to form a barchan.

These results show that seeds must be supplied with moisture and nutrients at the sowing site. For this purpose, local natural and industrial raw materials were analysed.

Sapropel and vermicompost stand out for their organic matter (58.7–62.4 %) and nitrogen (2.10–2.75 %) contents. Phosphorite waste is the main source of P_2O_5 , its content reaching 14.4 % in the mineralized mass (Figure 1). Glauconite (K_2O 6.80 %) and vermiculite (5.40 %) are slow-release sources of potassium, while bentonite and vermiculite are valuable as water-absorbing and water-retaining components. The fulvic acid content of poultry manure (7.27 %) is several times higher than that of the other materials.

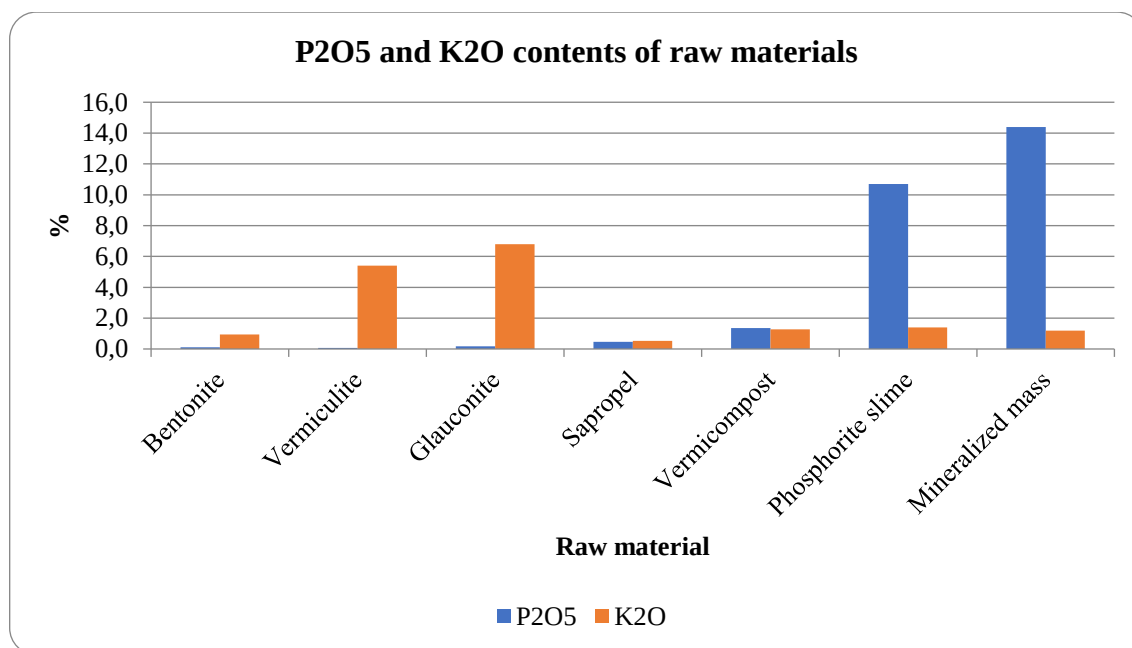


Figure 1. P_2O_5 and K_2O contents of the raw materials, %

Combined application of poultry manure and phosphorite waste makes it possible to obtain an organo-mineral fertilizer. Organic acids in the manure help convert the poorly soluble phosphorus compounds of phosphorite into plant-available forms. Phosphorus, in turn, is important for root system development and for plant tolerance to salinity and drought. Given the severe deficiency of mobile phosphorus and humus in the soils of the Aral Sea bed, such compositions, combined with bentonite or vermiculite and a hydrogel, could serve to retain moisture at the sowing site.

Conclusion

In 2025, seeds of 13 halophyte and xerophyte species were collected at the dried salt lake in Tamdy. The largest amounts were obtained from *Haloepelis perfoliata*, *Aeluropus lagopoides*,

Climacoptera lanata and *Karelinia caspia*. Seed ripening extends from September (*H. perfoliata*) to December (*H. strobilaceum*, *H. belangeriana*).

The species sown on the dried Aral Sea bed on 21 February 2026 emerged well in spring, but after the dry and hot summer only *H. perfoliata*, *Salicornia perennans* and *Kochia iranica* had survived by August. *S. perennans* was identified as the most promising species for introduction.

The main causes of low germination and survival are extreme substrate salinity, moisture deficit in the upper layer, drifting sand and harsh temperature conditions. Shifting the sowing date to late autumn–early spring and retaining moisture at the sowing site are the key requirements of the agrotechnology.

Among the local raw materials, sapropel, vermicompost and poultry manure are recommended as sources of organic matter and humic acids, phosphorite waste as a source of phosphorus, and bentonite and vermiculite as moisture-retaining components for preparing organo-mineral compositions.

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