Prospects for the introduction of fodder species *Artemisia* into culture

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Abstract. In many desert communities, the basis of pasture ecosystems are species of the genus Artemisia, which are edifiers of plant communities in the vast territories of the Central Asia desert zone. Sagebrush pastures with a diverse set of plant species and life forms are used in desert animal husbandry all year round. Artemisia spp. is good fodder pastures plants. Green twigs contain 16.9% protein, 4.4% fat, 39% nitrogen-free extractives. *Artemisia diffusa*, *A. turanica* are common on desert gray-brown and gray-earth soils with different granulometric composition, *Artemisia halophila* has a narrow ecological area confined to saline soils. The fodder mass of Artemisia spp. serves as the main type of sheep fodder and is especially appreciated in the autumn, winter and early spring periods. As a result of irrational use, the natural sagebrush pastures of deserts are degraded and need to restore their fodder productivity. All three wild–growing species – *Artemisia turanica*, *Artemisia diffusa*, *Artemisia halophyla* in culture conditions accelerate the passage of phenological phases in the process of ontogenesis. Individuals of species populations of sagebrush develop faster in cultural conditions than in natural sagebrush communities. In the culture conditions the process of ontogenesis, skeletal axes of the shrub are laid at the base of the maternal shoots in young individuals, in the second or third year of life, the tested species of sagebrush form a morphologically full-fledged life form of a semishrub with a feed productivity 3-5 times higher than the yield of natural pastures. In the conditions of Artemisia spp. culture, they grow well and quickly. Many individuals enter the fruiting season in the first year of life.

1 Introduction

Artemisia diffusa Krasch. and *Artemisia turanica* Krasch. are semi-shrubs 30–40 cm high with strongly dissected grayish leaves [1]. *Artemisia diffusa* and *Artemisia turanica* are widespread on desert gray-brown and gray soils of different mechanical composition. At the same time, *A. halophyla* Krasch. has a narrow ecological range, confined mainly to saline soils and does not extend these habitats [2]. *A. halophyla* is spread in the Aral-Caspian, Kyzylkum, and Karakum [2, 3]. Artemisia is resistant to abiotic stress [4].

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Fodder species of Artemisia are exceptionally resistant to grazing by animals (sheep) and characterized by wide ecological plasticity. It predetermines the possibility of growing them on different soils in terms of granulometric composition (clay, sandy) and degree of salinity. Artemisia coexist well in cooperative communities with forage shrubs and semi-shrubs. Seeds retain germination for 3–5 years [5].

Artemisia is exceptionally long-lived and pasture-tolerant [5].

Artemisia halophila Krasch. is a semishrub 20–80 cm high, with a root system of universal type, penetrating into the soil down to 3.5 m, much deeper than the roots of *Artemisia diffusa* and *Artemisia turanica*. Productive longevity is 12–18 years. Euxerophyte and halophyte [2] are more resistant to drought and heat, as well as to soil salinity, than *Artemisia diffusa* and *Artemisia turanica*. It is a good plant for developing salt marsh lands for fall and winter grazing.

Artemisia is a good forage for sheep, especially in the fall and winter. During regrowth period, green twigs contained 16.85% of crude protein, 15.95% of protein, 4.49% of fat, 39.06% of nitrogen-free extractive substances, and 12.68% of ash matter. Dry fodder mass retains 20–65 fodder units in different seasons throughout the year [5].

Artemisia halophila is more productive and eaten by sheep better than *Artemisia diffusa* and *Artemisia turanica*. It gives up to 1.5–2.5 t/ha of dry fodder, contains 8–10% of simple protein, 7% of crude protein, and 3.4% of fat. There are 50–60 fodder units in 100 kg of dry fodder. *Artemisia halophila* develops noticeably faster compared to other species of Artemisia.

The purpose of the article was to study the peculiarities of growth and development of some forage species of Artemisia in the conditions of culture in the desert zone of Central Asia.

2 Research methodology

The system of observations and records of Artemisia seeds germination, their growth, development, fruiting, seed and fodder productivity was carried out in accordance with the "Methodological guidelines..." [6].

The studies were conducted in two ecologically different areas of the Central Asian desert.

Piedmont desert of the Nishan "steppe". The experimental site is located at an altitude of 354 m above sea level. The soil cover is represented mainly by light gray soils. A characteristic feature of the soil profile is its layered structure: horizons of light, medium and heavy loams, as well as sandy loam alternate. The soils are largely saline and can be classified as saline. The content of water-soluble salts reaches up to 1.35–2.77% which are mainly Na_2SO_4, $CaSO_4$ and NaCl. According to the total amount of water-soluble salts, the considered soils are characterized by sulfate and chloride-sulfate types of salinization. Humus content in the rooting layer is 0.02–1.86%. Groundwater occurs at a depth of 12–14–20 m. Mean annual air temperature is +14.8°C, with maximum of +47°C and minimum of -27°C. The coldest month is January, with temperature sometimes dropping to -30°C. Mean annual precipitation is 222 mm [7].

Wormwood-ephemeral Carnabchul desert. The experimental site is located at an altitude of 310 m above sea level. The dominant soil type is light gray soil and transitional from light gray soil to gray-brown. Soils are of stratified structure: horizons of light loams are replaced by medium loams, gruss or sandy loams, non-saline and slightly saline. Humus is contained in insignificant amounts. In the upper layers, its content varies from 0.30–0.79 to 0.81%, and in the lower layers, its content drops to 0.17%. Groundwater occurs at a depth of 14–20 m. Mean annual air temperature is +16°C. In June–July it reaches 40–45°C in the shade, and in January it sometimes drops to minus 20–30°C. Relative humidity for the year

averages 30% in spring, and in summer it drops to 10–20%. Mean annual precipitation is 167 mm [8].

3 Results and discussion

In the process of ontogenesis of *Artemisia turanica*, *Artemisia diffusa* and *Artemisia halophila* fodder species, important stages in their life cycle are the phases of flowering and fruit formation in the conditions of the Central Asian desert. In the studied species of Artemisia the inflorescence is a anthodium of cylindrical form, strongly pubescent. Flowers are usually arranged three to seven on one bare peduncle of the anthodium, with five stamens. Usually from one inflorescence consisting of five to seven flowers only one or two produce fruit, the rest are sterile. On average, there is one developed fruit per anthodium.

All Artemisia flowers are of both sexes and very small – about 2–2.5 mm long. In the anthodium, the outermost flowers bloom first, followed by the middle flowers, but without a definite sequence.

At the very beginning of flowering, the upper edges of the flower petals are closed. Then the petals diverge, and the tips of the stamens are seen from the top of the flower. It soon burst, and a mass of light-yellow pollen fills the top of the opened flower. During the day, the stamens extend further out of the flower and pollinate. On a still sunny day, the pollen in the flower can be seen for hours, but in strong winds it is blown away. If such a flower with pollen is carefully separated and unfolded under a magnifying glass, one can see inside it a short column and close 2 lobes of the stigma. They have their own pollen, but it does not germinate, as at this time the stigma is not mature.

In a flower in which the stamens have just begun to pollinate, the upper edge of the stigma lobes is at the level of the central part of the flower. No growing pollen stigmas or columns of the same age were found in the pollen tubes examined.

By the end of the first or second day of flowering there is an increased growth of the column, the lobes of the stigma are brought out above the corolla of the flower and widely extended. At this time, the stigmas are firm and shiny due to the secretion. The flower remains in this state for one more day. Since its pollen is all expelled by this time, it can only be pollinated by the pollen of another flower. Later, the stigma loses viability, which can be determined by its appearance (loss of turgor), shrivels up, but does not always fall off. Often, many days after pollination, the dried lobes of the stigmas of several flowers can be seen in the developing anthodium.

The anthodium blooms for 4–12 days depending on the number of flowers. Thus, the anthodium that bloomed on September 25 faded on October 4–5. Flowers in anthodium are set from about the middle of July, and their development lasts until the end of September. Flowering begins in late September to early October.

Experiments were conducted to find out the type of pollination of Artemisia. On September 25, anthodia that were supposed to bloom soon but had not yet bloomed were carefully isolated with bags. On November 10, all isolated anthodia were cut and carefully examined in the laboratory. We isolated 127 anthodia of *Artemisia turanica*, which contained 1013 flowers, but no seeds were set, and 58 anthodia of *Artemisia diffusa*, which contained 808 flowers, but no ripe seeds.

To determine seed set in Artemisia when pollinated with pollen from flowers of other anthodia of the same plant, 6 twigs on 6 plants were isolated. There were 13, 15, 16, 17, 31, and 45 anthodia on the twigs. There also were 105, 108, 158, 129, 214, and 321 flowers in them, respectively. No set seed was found in these anthodia in November. In the study of anthodia developed without isolation under conditions of free pollination, in *Artemisia turanica* and *diffusa*, 100 anthodia each in three repetitions of wilted seeds were examined. On average it was 35 and 26%, respectively.

Thus, autogamy and geitonogamy are not characteristic of *Artemisia turanica* and *diffusa*.

In the ontogenetic development of forage species of Artemisia, the fruiting phase is the final stage in their life cycle.

Artemisia turanica, Artemisia diffusa and *Artemisia halophila* have an obovate seed, flattened on the sides. Fruit shells are light gray, with ribs clearly visible on the surface of the seed. Seed pod is 1.5–1.8 to 1.9–2.0 mm long, and 0.6–0.8 mm wide.

Seeds (fruits) of forage Artemisia species germinated under favorable conditions of thermal and moisture regimes. In this regard, we have carried out special studies to establish the optimal regimes for germination of Artemisia seeds. Experiments on the influence of temperature and humidity on the germination of *Artemisia diffusa* seeds showed that more vigorous germination was observed at variable temperatures (31–13–31 °C). Also, even germination of seeds occurred when they were frozen for four days and then germinated in chambers with a temperature of 20–25 °C. Such experiments were conducted with seeds one year after they were collected.

Experiments conducted to study the germinability of freshly collected seeds of *Artemisia diffusa* and different years of their storage allowed us to conclude that the laboratory germinability of Artemisia seeds is about 30% with fluctuations in the range of 13–47%. Seeds have a post-harvest dormancy period from which they emerge (within 1–2 years) when stored in laboratory conditions or after 30–40 days when stratified.

Laboratory germination of halophila seeds showed that freshly harvested seeds had a germination of 46–63%. After 14–month storage it increased to 75.3%. Field germination was much lower and amounted to 10%.

Artemisia seeds sown in February sprouted in mid-April. The onset of phenophases was as follows: shoot formation in May, budding in mid-July, and flowering in September. All populations of Artemisia develop well in the first year with often fruiting. In subsequent years, the onset of phenophases during ontogenesis was accelerated and was as follows: regrowth was in April, intensive growth was in May, budding was in June, flowering was in August, autumn vegetation took place in September–October, and seed ripening was in November. The growing season is 230–237 days long.

Table 1 summarizes the dynamics of stand density and survival rates of Artemisia species under culture conditions in piedmont and wormwood-ephemeral desert. In the first year, survival of individuals of all species ranged from 42.2–51.9% of the maximum number of emerged seedlings in spring (Table 1).

Table 1. Dynamics of stand density and survival rate of Artemisia species during cultivation in Central Asian deserts

Plant	1st year		2nd year	3rd year	4th year	5th year	6th year
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Piedmont desert of the Nishan "steppe"							
Artemisia turanica	98,600±2,618 100	44,250±1,200 44.8	33,600±6,976 34.08	42,960±8,628 43.57	36,100±7,860 36.61	32,500±6,130 32.96	23,470±4,920 23.8
Artemisia diffusa	24,200±5,210 100	12,550±846 51.86	13,940±2,080 57.6	13,900±2,010 57.44	13,600±2,162 56.2	12,700±1,900 52.48	9,740±660 40.2
Artemisia halophila	84,800±7,100 100	35,850±8,540 42.27	31,000±4,760 36.55	29,840±3,600 35.19	17,500±2,176 20.64	8,300+2,480 9.79	7,100±1,920 8.37
Wormwood-ephemeral Carnabchul desert							
Artemi	32,800±9,	17,000±4,	14,600±2,	10,200±1,	9,500+2,3	8,900±2,0	6,600±1.

sia haloph ila	920 100	420 51.9	530 44.5	480 31.1	20 29.0	80 27.1	14 20.1

Note: in the numerator absolute figures in pcs/ha, in the denominator – %.

The survival rate of plants of all Artemisia species gradually increases with age and is as follows: by the end of the sixth year of vegetation in the piedmont desert, it amounted to 23.8% in *Artemisia turanica* and 40.2% in *Artemisia diffusa*. In wormwood-ephemeral desert by the end of the sixth year of vegetation, the survival rate of individuals in *Artemisia halophila* was 20.1%. *Artemisia halophila*, sown on gray-brown soils of light mechanical composition in South-Western Kyzylkum, gave good sprouts. In spring there were 188,120 plants on 1 ha. By the end of the first year, 22.6% of the plants had survived, and by the end of the fourth year – 6.3%. Being a plant of saline habitats, when transferred to upland conditions, *Artemisia halophila* gradually dies both in the piedmont desert and in South-Western Kyzylkum. Only the ecological conditions of the Carnabchul desert turned out to be the most favorable for the growth of *Artemisia halophila*.

Emerging seedlings barely reach 1.5–2 cm in height in April–mid-May. It is 9.5–13.5 cm in late June, and 19.6–22.1 cm in August. At one year of age in the piedmont semi-desert, the height of Artemisia individuals in the population reached 21.9–26.1 cm, while in wormwood-ephemeral it reached 36.7–41.0 cm (Table 2). In the second year, the height of bushes of all examined species is slightly higher. In subsequent years, it is at about the same level in all examined Artemisia species. At the same time, new twigs are formed. When growth is complete, generative twigs dry out to more than half of their length. The species tested in the wormwood-ephemeral desert are well developed and characterized by greater stature.

In natural growing conditions on gypsum light medium and light loamy gray soils, the roots of *Artemisia diffusa* penetrate to a depth of 80–120 cm. Lateral roots are usually well developed and extend horizontally up to 1 m. The majority is concentrated at a depth of 30–40 cm. There are many ephemeral roots in the upper-most layers of soil. Under cultivation on light loamy soils, root system develops faster than the above-ground part. At the age of one year the roots penetrate to a depth of 95–120 cm, and at the age of 2.5 years in culture to a depth of 280 cm. The root system of adult plant does not have a well-defined main root due to severe reduction.

Table 2. Growth performance of some Artemisia species during cultivation in Central Asian deserts

Plant	Plant height, cm					
	1st year	2nd year	3rd year	4th year	5th year	6th year
Piedmont desert of the Nishan "steppe"						
Artemisia turanica	26.1±1.28	40.07±1.26	32.5±0.7	42.8±0.84	29.6±0.4	45.8±1.8
Artemisia diffusa	21.94±1.53	38.5±0.7	33.2±1.22	41.16±1.35	30.9±0.68	40.9±0.74
Artemisia halophila	25.4±3.41	51.37±5.0	43.3±3.0	54.41±3.53	45.6±2.01	62.4±1.79
Wormwood-ephemeral Carnabchul desert						
Artemisia turanica	36.7±2.34	63.8±0.95	36.3±1.4	53.2±5.34	41.6±16.5	31.8±4.07
Artemisia halophila	41.0±1.62	69.7±1.69	36.4±2.3	51.7±1.52	46.6±2.65	64.2±5.41

In the Carnabchul Desert, we dug up root systems of *Artemisia diffusa* in the wild and in cultivated areas. Soils are light gray soils, light loamy and sandy loam by mechanical

composition. Roots were dug from 5-year individuals. As diggings showed, the root system of *Artemisia diffusa* penetrated to a depth of 120–135 cm. In general, *Artemisia diffusa* is highly branched, with a well-developed root system adapted to utilize the soil moisture of precipitation.

During 1–2 years of cultivation, the life form of semi-shrub is fully formed. *Artemisia diffusa* and *Artemisia turanica* have a height of 25–45 cm with 13–30 shoots of the first order, and *Artemisia halophila* is 41–62 cm high with 15–20 shoots of the first order.

At all types of pastures, where Artemisia dominate in the herbage, they have relatively equalized stock of eatable fodder by seasons of the year. In addition, Artemisia yields fluctuate less from year to year than ephemerals and ephemeroids.

Cultivation of Artemisia generates relatively high yields of fodder mass. According to According to Nechaeva [5], fodder yield of artificial Artemisia in the 3rd–4th year is 0.9–1.4 t/ha of gross stock.

According to our data, the yield of Artemisia in the first year of life is low. In the second year, in the piedmont desert, the yield of *Artemisia turanica* and *diffusa* was 0.21–0.27 t/ha, and of *Artemisia halophila* – 0.45 t/ha. In the wormwood-ephemeral desert it was 0.48 and 0.17 t/ha of dry mass, respectively. In subsequent years, the yield reached 1.1–1.45 t/ha. Studies have shown that Artemisia species become most productive at 8–12 years of age.

The accumulated scientific information on morphology, biology and ecology of forage species of *Artemisia* and our data on the peculiarities of growth and development of cultivated Artemisia in the conditions of the Central Asian desert give grounds to make an ecological and biological portrait of these species.

Artemisia turanica Krash. The morphologically fully formed life form of semishrub *Artemisia turanica* has numerous generative shoots that are thin, and located at the upper part. Lower leaves are petiolate, up to 1.5–2.0 cm long, and twice or thrice pinnately dissected. Middle leaves are sessile, less complexly dissected, and with pinnately dissected auricles at base. The uppermost leaves are entire and linear.

Anthodia are sessile, far-spaced, ovate, and small in a broad loose panicle. Flowers are from 3 to 5. The seeds are small and grayish-brown in color.

Seed productivity of Artemisia in natural growing conditions is not high. In the wormwood-ephemeral desert, there were 195 seeds per plant. The seed yield was 1.8 kg/ha. In the same zone, the yield of clean seed was 10.2 kg/ha in lightly grazed pasture and no more than 4 kg/ha in heavily grazed pasture.

Seed productivity of Artemisia under cultivation increases, and seed yields in the wormwood-ephemeral desert reach 15–25 kg/ha depending on plant age.

Artemisia diffusa Krash. is one of the most widespread plants of southern deserts. Root system of universal type, penetrating to a depth of 0.8–2.5 m depends on the physical and chemical conditions of the soil. It is a drought-tolerant plant that has adapted well to life in desert conditions. *Artemisia diffusa* starts vegetating in early spring – in February–early March with the development of shoots, the intensive growth of which continues until mid-June.

From the second half of June until September, Artemisia is in an anabiotic state when most leaves fall off. In the fall, when daytime temperatures drop, secondary vegetation begins. Artemisia blooms and fruits in October–November. Individuals of Artemisia are viable for up to 20–30 years.

Artemisia diffusa is a very valuable fodder for sheep, goats and camels. Fodder value is represented by shoots, anthodia, which are well eaten in the fall–winter period. It is eaten satisfactorily in spring, and worse – in summer.

Protein content comprised 21.1–4.6%, fat was 11.7–1.8%, nitrogen-free extractive substances were 42.7–33.1%, and fiber was 54.3–22.9%. The highest protein content is

observed in the phase of shoot regrowth and the beginning of budding. It decreases during fruiting, especially in the winter season. A 100 kg of dry fodder contains 26.6–61.9 fodder units.

Artemisia halophila Krasch. is a semi-shrub, 20–40 cm high. Leaves of vegetative shoots and lower stem leaves are 1–4 mm long-petiolate and succulent. The lamina is oblong or linear, twice pinnately divided. Middle and upper leaves are sessile, pinnatifid. Outer leaves are small, oval, greenish-gray, and densely hairy. The flowers are often reddish.

Communities of *Artemisia halophila* are always confined to saline habitats and do not extend beyond their limits. It is a good forage plant for sheep in the fall-winter period, especially after the first rains and frosts. It is very close to other desert Artemisia species in forage value.

The growing season lasts 300–330 days. With a warm winter, regrowth begins in late January. The most intense shoot growth continues until mid-June, when the plant begins to bud. It blooms from mid-September and the seeds mature in late October.

Artemisia halophila is a very promising fodder plant for creation of fall-winter pastures.

4 Conclusion

Artemisia constitute the main pasture fodder in semi-desert and desert areas of Central Asia. Sheep eat it better than other animals: well in spring, satisfactory and poor in summer, good and very good in fall and winter. In desert zone pastures, Artemisia is the main bait feed and source of vitamins in the forage.

All three wild species – *Artemisia turanica*, *Artemisia diffusa*, *Artemisia halophila* under cultivation conditions accelerate the passage of phenological phases in the process of ontogenesis. Individuals of Artemisia species populations develop faster under cultivation conditions than of natural Artemisia communities. In the process of ontogenesis under cultivation conditions, skeletal bush axes of young individuals at the base of maternal shoots are laid down. In the second–third year of life examined species of Artemisia form morphologically full-fledged life form of semi-shrub with fodder productivity 3–5 times exceeding the yield of natural pastures.

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