Growth and development of the wild-growing subshrub *Salsola orientalis* SG Gmel. in culture under conditions of the Central Asian desert

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**Abstract.** In terms of life form *Salsola orientalis* S.G. Gmel. is a semi-shrub; its height reaches 40–60 cm; in terms of ecology, it is a haloxerophyte, extremely resistant to salt stress, air, and soil droughts. *Salsola orientalis* is a highly nutritious forage plant containing up to 20% protein in the budding phase. High resistance to environmental stress and good forage value allow us to consider it as a promising plant – its introduction into culture allowed restoring the forage productivity of degraded pastures in the Central Asian desert. The features of growth and development of *Salsola orientalis* were studied for ecological and biological characteristics and the possibility of introducing it into culture. It was found that the laboratory germination of seeds of the wild-growing half-shrub *Salsola orientalis* was quite high – 20–60%; field germination was very low – 0.1–1.7%. The survival rate of seedlings in young plants depends on environmental conditions and plant density. Under conditions of the Central Asian desert the plants basically die in the first year, especially in the germination phase; in the second year we registered insignificant losses; in subsequent years the number of plants stabilized. *Salsola orientalis* was found to be a fast growing plant, forming a normal half-shrub in the first year of life. The high ecological stability of *Salsola orientalis* in combination with its deeply penetrating and powerfully developed root system ensures vigorous and rapid growth. Under conditions of the Central Asian desert *Salsola orientalis* yields 1.3–1.7 t/ha of dry fodder mass, which is 4–5 times higher than the fodder productivity of natural desert pastures.

1. Introduction

*Salsola orientalis* S.G. Gmel. is a strongly pubescent haloxerophytic dwarf shrub; its height varies from 15 cm to 50–70 cm; its gray-green annual shoots are covered with curly fibrillae. The form of the bush is sprawling and crumby.

The range of *Salsola orientalis* is quite extensive – it covers Dzungaria, Afghanistan, China; it is found in Dagestan, Central Asia, Aral-Caspian Sea, Balkhash, KyzylKum, Karakum, mountainous Turkmenistan, and in the Amu Darya region. The northern boundary of *Salsola orientalis*’s range lies above 50 °N; the southern boundary extends to the deserts of Western India. Communities with phytocenotically significant participation of *Salsola orientalis* are distributed over large areas of Kazakhstan and Central Asia – 318.3 thousand km², which is 19% of the total area of deserts [1].

*Salsola orientalis* grows on serozems, takys, gray-brown soils, on thin sands; in places its range extends quite high into the mountains and it grows on the slopes of outlier mountains [2].
The ability of semi-shrub halophytes to live the full life cycle under these conditions is realized due to structural, physiological, and biological adaptations: succulent organization of the leaf photosynthetic apparatus [3], multilayer epidermis, thickening of the cuticle [4] and belonging to the C₄-type of photosynthesis. This ensures more economical and efficient use of water for transpiration in comparison with C₃-plants consuming fewer water units to fix a unit of CO₂ and to form a unit of dry matter [5].

*Salsola orientalis* is a highly nutritious forage plant containing a fairly large amount of protein (12.06–20.28%), nitrogen-free extractives (35.20–45.98%), and a significant amount of fat (2.70–3.55%) and ash (14.43–23.71%) substances. Depending on the season 100 kg of dry feed contains from 32 feed units to 50 feed units. On desert pastures, it is a highly valuable food for sheep and camels; the level of its consumption by cattle is high throughout the year, especially in autumn and winter.

The noted important ecological properties of *Salsola orientalis* – high drought resistance and salt tolerance, combined with good fodder qualities – give grounds for introducing it into culture in desert areas.

The purpose of the work was to experimentally substantiate the possibility of introducing *Salsola orientalis* into the culture to restore the forage productivity of degraded pastures in the Central Asian desert.

2. Materials and methods

The experimental site was located at an altitude of 310 m above sea level. The local soils are light gray, not saline or slightly saline. They, as well as the main territory of the wormwood-ephemeral desert, are characterized by light and medium texture, layered structure with insignificant gypsum. The content of humus in the upper layers ranges from 0.30–0.79% to 0.81%; for the lower layers this indicator drops to 0.17%. Groundwater level ranges from 14 m to 20 m. The average annual air temperature is 16°C above zero, in June–July in the shade it reaches 40–45°C above zero, in January it sometimes drops to 20–30°C below zero. The mean annual relative air humidity is 30%; in spring, especially in summer, it drops to 10–20%. The average annual amount of precipitation is 167 mm.

Field experiments were conducted according to the “Guidelines for the mobilization...” [6]. The following observations were conducted on experimental crops of *Salsola orientalis* taking into account dynamics of the number and survival rate of young seedlings, dynamics of plant growth, growth and development of the root system, and the formation of forage mass.

3. Results and discussion

3.1. Phenological observations

Seedlings of *Salsola orientalis* emerge in the period from late February to late March, in cold spring they emerge in April. Intensive branching begins (sprout formation) in May; budding begins in late May – early June and lasts 10–12 days. The flowering phase begins in June–July and lasts until the end of September. The fruiting period is quite long: on plants of the first year of vegetation, samara fruits appear on September 10–25; the first ripe fruits appear in mid-October; mass ripening is observed in perennials on October 20; for annuals it lasts from late October to early November. For perennials, regrowth begins, as a rule, in March – early April, but sometimes earlier.

3.2. Laboratory and field germination of seeds

Laboratory seed germination is quite high, but varies greatly depending on the quality of seeds, crop conditions, collection time, as well as storage methods and conditions. Laboratory germination of seeds collected in natural thickets was 20–60%.

Field germination at different sowing dates was low: at the January sowing period it reached 1.71%, at other times it was in the range of 0.06–1.65% (Table 1).
Table 1. Field germination of Salsola orientalis seeds in the wormwood-ephemeral desert.

| Sowing date | Germinating seeds sown on 50 m² | Pcs per 50 m² | % of the number of sown seeds |
|-------------|---------------------------------|---------------|-------------------------------|
|             | Crops of 1st year               |               |                               |
| 26.I        | 2000                            | 34.3          | 1.71                          |
| 22.II       | 2000                            | 33.0          | 1.65                          |
| 31.III      | 2000                            | 2.25          | 1.11                          |
|             | Crops of 2nd year               |               |                               |
| 5.XII       | 3000                            | 1.75          | 0.06                          |
| 29.I        | 3000                            | 3.0           | 0.10                          |
| 15.II       | 3000                            | 11.5          | 0.38                          |
| 14.III      | 3000                            | There were no shoots | |

3.3. Survival rate of seedlings and adult plants

Table 2 presents data on the survival rate of Salsola orientalis plants. The number of seedlings in all ecotypes was in the range of 3.5–7.3 thousand pcs/ha. The survival rate of seedlings by the end of the first year of life in all ecotypes was quite high. In subsequent years, in populations with a high initial density, a significant number of plants died. In populations with a low planting density, the mortality rate was insignificant. The survival rate of plants apparently depended on their density, which significantly aggravated the competition between plants for moisture and elements of mineral nutrition.

Table 2. Dynamics of density and survival rate of Salsola orientalis in culture in the wormwood-ephemeral desert.

| Salsola orientalis ecotype | 1st year | 2nd year | 3rd year |
|---------------------------|----------|----------|----------|
|                           | Spring   | Autumn   | Spring   | Autumn   | Spring   | Autumn   |
| Mubarekchul               | 6600 ± 2620 | 7340 ± 2200 | 6460 ± 1260 | 5740 ± 1640 | 78.2 |
| Kyzylkum                  | 3540 ± 1360 | 4300 ± 1370 | 4100 ± 1360 | 6000 ± 2320 | 103.9 |
| Kyrgyz                    | 7300 ± 1200 | 7140 ± 1190 | 7140 ± 1200 | 7640 ± 1240 | 104.6 |

The initial stand density of seedlings increased in accordance with an increase in the seeding rate of seeds. In the first year, it varied depending on the option of the experiment in the range of 2.2–14.1 thousand pcs/ha; in the second year, it varied in the range of 2.0–7.7 thousand pcs/ha. By the end of the growing season on plots with a seeding rate of 1 kg/ha of seeds, the survival rate of seedlings was 100%; in the second year it was 78.4%, which at increased seeding rates (12–15 kg/ha) of seeds was 38.6% and 54.4%, respectively (Table 3).

Table 3. Dynamics of density and survival rate of Salsola orientalis plants depending on the seeding rate in the wormwood-ephemeral desert.

| Seeding rate, kg/ha | 1st year | 2nd year | 3rd year |
|---------------------|----------|----------|----------|
| 1.0                 | 2200 ± 560 | 2600 ± 80 | 2040 ± 486 | 2140 ± 518 |
|                     | 100      | 100      | 78.4     | 82.8     |
In the populations of the first vegetation year, the mortality rate of seedlings and young plants was quite high; in the second and third years, it decreased to 5–6%. On plots with a low seeding rate and, accordingly, with a low plant density, starting from 2nd vegetation year, the number of *Salsola orientalis* plants per unit area increased due to self-seeding.

### 3.4. Plant growth dynamics

All ecotypes of *Salsola orientalis* in the wormwood-ephemeral desert were characterized by rather rapid growth and development (Table 4). Thus, by the end of the first year of life, the height of plants in different ecotypes averaged from 52.8 cm to 59.8 cm. In subsequent years, it was approximately at the same level.

| *Salsola orientalis* ecotype | Plant height, cm | 1st year | 2nd year | 3rd year |
|-----------------------------|------------------|---------|---------|---------|
| Mubarekchul                 |                  | 15.V    | 27.VI   | 27. VIII|
|                             |                  | 12.2    | 40.2    | 59.8    |
|                             |                  | 53.4 ± 3.47 | 51.1 ± 6.6 |
| Kyzylkum                    |                  | 2.7     | 42.4    | 52.8    |
|                             |                  | 51.6 ± 2.2 | 59.0 ± 5.4 |
| Kyrgyz                      |                  | 7.6     | 41.9    | 55.4    |
|                             |                  | 50.7 ± 4.6 | 58.5 ± 4.8 |

Thus, *Salsola orientalis* in culture under conditions of the wormwood-ephemeral desert is a fast-growing dwarf shrub.

### 3.5. Root system *Salsola orientalis*

In the wormwood-ephemeral desert, the three-year-old *Salsola orientalis* root system was excavated on experimental crops. It was powerful, penetrating deep into the soil – to a depth of up to 400 cm. At a depth of 20 cm, the main root decomposes into many lateral roots that go vertically downward. At a depth of 160 cm lies a meter thick light loamy layer of soil. In this layer, we registered an increased number of fibrillae on the lateral roots. At a depth of 280–320 cm, the roots penetrate into a light sandy loam layer with pebbles and an interlayer of silt. Here, the soil moisture noticeably improves, and accordingly the number of fibrillae significantly increases. Farther, the roots deepen to 400 cm of the soil sand layer. Here all the roots bear a large number of absorbing roots.

Thus, in the wormwood-ephemeral desert, *Salsola orientalis* forms a powerful root system that penetrates deeply into the soil, which ensures uninterrupted water supply to plants under arid conditions of the Central Asian desert.

### 3.6. Feed productivity

*Salsola orientalis* in culture is a fairly high-yielding plant. Its yield, depending on age, ecotype, meteorological conditions, and agricultural techniques, varies from 0.4 t/ha to 1.7 t/ha of dry fodder mass.

| *Salsola orientalis* ecotype | Plant height, cm | 1st year | 2nd year | 3rd year |
|-----------------------------|------------------|---------|---------|---------|
| Mubarekchul                 |                  | 15.V    | 27.VI   | 27. VIII|
|                             |                  | 12.2    | 40.2    | 59.8    |
|                             |                  | 53.4 ± 3.47 | 51.1 ± 6.6 |
| Kyzylkum                    |                  | 2.7     | 42.4    | 52.8    |
|                             |                  | 51.6 ± 2.2 | 59.0 ± 5.4 |
| Kyrgyz                      |                  | 7.6     | 41.9    | 55.4    |
|                             |                  | 50.7 ± 4.6 | 58.5 ± 4.8 |

Thus, *Salsola orientalis* in culture under conditions of the wormwood-ephemeral desert is a fast-growing dwarf shrub.
**Salsola orientalis** in culture is a highly productive plant forming a relatively high yield of forage mass per unit area. Among the tested ecotypes of *Salsola orientalis*, the highest productivity was registered in the Mubarekchul ecotype, the average yield of which was 1.7 t/ha; the yield of dry fodder mass the Kyzylkum ecotype was low – 0.7 t/ha (Table 5).

Based on the above, the prospects of introducing the subshrub *Salsola orientalis* into the culture for restoring the forage productivity of degraded pastures in the Central Asian desert seem quite good.

### 4. Conclusion

The totality of the data obtained in the course of research gives grounds to characterize the ecological appearance of *Salsola orientalis* in terms of life form as a half-shrub; its height reaches 51–59 cm; in terms of ecology it is a haloxerophyte, combining the features of euhalophyte and xerophyte with a powerfully developed and rapidly growing root system deeply penetrating into the soil and economically consuming moisture for transpiration and effectively using water and mineral resources with C₄-type of photosynthesis. Due to these ecological and biological characteristics, *Salsola orientalis* successfully passes the full life cycle in the first year under harsh xerothermal conditions of the Central Asian desert and enters the fruiting season forming a satisfactory amount (0.5–1.3 t/ha) of dry feed mass.

Scientific results characterizing the adaptive and productive properties of *Salsola orientalis* indicate the prospects of introducing it into culture under conditions of the Central Asian desert to restore the forage productivity of degraded pastures.

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