

Xerohalophyte semi-shrub *Camphorosma lessingii* Litv.: selection by shrub forms in the Caspian semi-desert conditions

Elmira Shamsutdinova*, Zebri Shamsutdinov

Federal Williams Research Center of Forage Production & Agroecology, 1 Nauchnyi gorodok, Lobnya, Russia

Abstract. *Camphorosma lessingii* is a perennial plant, a semi-shrub by life form, and a haloxerophyte. It is tolerant to drought and heat, and to salt stress. The growing season is 235–245 days long. It is a good fodder plant suitable for recreating permanent pastures, both natural and with semi-shrubs of *Kochia prostrata* and *Salsola orientalis*. The objective of the study was to analyze and evaluate the intraspecific diversity of *Camphorosma lessingii* by its shrub forms. During ontogenesis, when *Camphorosma lessingii* enters the budding phase, plants are differentiated into three types by forms. The first type is the prostrate forms, where the central stem is weakly structured or absent. The second type is the prostrate-climbing forms, where the central stem is well-defined, with many lateral shoots. The erect forms are the third type, with a single central inflorescence shoot (stem). A prostrate *Camphorosma lessingii* proved to be the most productive and resistant to abiotic stresses. With this form of *Camphorosma lessingii* as the parent material, the pasture variety Grace was cultivated. This variety is characterized by high bushiness, leafiness, and drought resistance, as well as winter hardiness, yield of fodder mass and seeds, and resistance to diseases and pests. The productivity of *Camphorosma lessingii* variety Grace reached 2.0 t/ha of dry fodder mass, exceeding the yield of the standard one by 0.7 t/ha.

1 Introduction

The arid-pasture complex of Russia unites a vast in area and ecologically isolated part of the country's territory with its extremely arid climate and extreme natural conditions. Natural arid pastures occupying vast areas are the basis of pasture fodder for sheep, goats, horses and camels [1].

However, as a result of irrational pasture use, these natural forage lands are degraded and need phytomelioration based on the use of dominant species of climax communities. One of the promising species of fodder plants for these purposes is the xerohalophyte semi-shrub *Camphorosma lessingii* Litv.

Camphorosma lessingii is a xerohalophyte, rather resistant to drought and heat, and to salt stress. It is a perennial plant of Chenopodiaceae family, suitable for developing

* Corresponding author's e-mail: darplant@list.ru

polydominant highly productive pasture ecosystems, both natural and with other semi-shrubs and grasses. From early March to "deep winter" (December) it is a source of green vitamin fodder in arid regions of Russia. In terms of fodder qualities, it is suitable for many animal species, in particular for sheep, cattle, and horses.

The biogeography of *Camphorosma lessingii* distribution [2, 3], phylogeny [4] and its origin [5, 6], and onset and formation of C4 photosynthesis type [7, 8, 9] in Chenopodiaceae species are well studied. The role of *Camphorosma lessingii* in the development of fall-winter highly productive pasture ecosystems in arid zones of Central Asia has been described [10, 11].

It grows on light- and medium-saline gray-brown and desert-sandy soils of different mechanical composition (from clay to sandy).

Camphorosma lessingii is a plant that exhibits certain biological features during ontogenesis. After seed germination, and during the first months of its development, the plant forms a rosette structure [12]. This is due to the rapid development of the root system, which penetrates deep into the soil, while the growth of the main stem is slowed down. However, in late April, there is an accelerated growth of the main stem, which affects the further shape and structure of the plant. Each new leaf unfolds in the axil where axillary buds are formed. From these buds, lateral generative and elongated vegetative secondary shoots begin to grow. These shoots will determine the shape and structure of the plant for decades [12]. The main axial shoot (stem) appears first, followed by generative secondary shoots. Secondary shoots develop from a very short internode zone and remain vegetative at first. However, over time they begin to grow vigorously, forming long internodes about 1.5–2.0 cm long. Thus, the plant forms a new group of vegetative shoots and inflorescences.

The growth of the main stem and secondary generative shoots continues until the beginning of fruit formation. This process completes at the end of the ontogenesis of plant development [13]. It is important to note that when passing into the budding phase, plants are divided into three types according to the shrub forms, each of which has its own features in the structure and growth of shoots. The first type of shrub is characterized by a prostrate form, where the central stem is either absent or weakly structured. It is replaced by a secondary generative shoot, which becomes the main stem of the plant. The second type of shrub is a prostrate-climbing form. It has a well-defined central stem with many secondary shoots. Its internodes in the middle part of the shoot become more elongated. The third type of the shrub is an erect form, where there is only one central shoot (stem) with an inflorescence. At the base, there are many elongated vegetative shoots of medium length.

The objective of the study was to select a promising plant of *Camphorosma lessingii* as a parent material for formation of a highly productive drought-resistant and salt stress tolerant variety, which guarantees obtaining 1.8–2.0 t/ha of dry fodder mass in the conditions of the Caspian semi-desert with the yield of natural pastures of 0.3–0.5 t/ha.

2 Materials and Methods

Studies were conducted in the Caspian reference site (Solenozaïmishchensky station, Astrakhan Oblast) in the semi-desert zone.

The experimental site was located on a slightly sloping Early Khvalyn terrace. Soils at this site are brown semi-desert soils with solonets content within 5–10%. Soil-forming rocks consist of loesslike saline loams, which alternate with saline clays and lenses of alluvial sands.

Granulometric composition is mainly represented by light and medium loamy soils, and in some cases sandy loamy soils are also found. The climate in the area is characterized by

sharp continentality and aridity. Active temperatures sum ranges from 3,300 to 3,600°C, and can reach high values in summer, with 41–44°C in the study area. Mean temperatures are about 24.5–25.5°C.

Rainfall in the area averages 250–260 mm, but in some years this figure can be below 200 mm.

Field studies were conducted in collection, breeding and agronomic nurseries using the "Methodological guidelines for breeding and primary seed production of perennial grasses" [14] and "Methodological guidelines for mobilization of plant resources and introduction of arid fodder plants" [15].

3 Results and Discussion

For several years we have conducted studies to determine quantitative differences between three structural types (prostrate, prostrate-climbing and erect) in biological traits and economically useful properties of *Camphorosma lessingii*'s plants. The results of the analysis, show that there are differences between these structural types. They are especially significant when comparing the first and the third types. These two types of *Camphorosma lessingii* individuals differ in the number of generative shoots and comprise 6 ± 0.31 in the first type, and 1 ± 0.12 in the third type. It also differs in the number of vegetative shoots being 3 ± 0.37 in the first type, and 8 ± 0.82 in the third type. The length of generative shoots shows an opposite tendency. The first type has 46.5 ± 2.10 cm shoots, while the third type has a longer shoots length of 52.3 ± 1.68 cm. The same happens with the length of inflorescences. The third type has 28.5 ± 1.21 cm inflorescences, while the first type has 25.7 ± 0.62 cm inflorescences. The number of skeletal shoots is also twice as high in the first type as in the third. In all three plant forms, the lower shoot is set at 0.5 cm from the soil surface.

The most productive, both in terms of fodder mass and seeds, are the prostrate forms. Individual fodder mass of *Camphorosma lessingii* had an average of 14.8 ± 0.23 g. Seed mass was 4.9 ± 0.83 g, respectively. The lowest productivity was characterized by erect forms, which had three times lower fodder mass compared to the prostrate forms. Seed productivity of these forms was also two times lower than that of the prostrate forms.

Such an important indicator as the number of regeneration buds is also in direct dependence on the number of generative shoots, because the regeneration buds are mainly located on these shoots. The number of renewal buds in prostrate *Camphorosma lessingii* averaged 517 ± 8.17 per plant of the first year of life, while in erect forms it was only 98 ± 2.33 .

Differences in individual productivity of two forms of *Camphorosma lessingii*, namely between prostrate and erect, persist in the second year of vegetation. Prostrate forms in terms of individual productivity maintained the same tendency as in the first year of life, exceeding erect forms in fodder mass by 3 times (78.7 ± 5.82 and 27.3 ± 4.86 g).

In spring (April), we excavated the root systems of each plant form. The data obtained allowed us to establish that the underground part of each form (individual) of *Camphorosma lessingii*, is quite different in many respects.

The deepest penetrating root system was formed by erect forms with a length of 189 ± 8.7 cm. Root of the prostrate forms penetrates to a depth of 149 ± 7.7 cm. The prostrate and prostrate-climbing forms have a dense network of the main and secondary roots, 18 and 14, respectively. The erect forms has the smallest number of the main (6) and secondary roots (4).

The highest root mass is 7.9 ± 2.6 g in prostrate forms, the average root mass is 6.5 ± 2.1 g in prostrate-climbing forms, and the lowest mass is 6.2 ± 1.3 g in erect forms. The highest total root length was in the prostrate forms and comprised 305.7 ± 21.4 cm, followed by the

prostrate-climbing forms with 260.3 ± 14.5 cm root length. The lowest branching and soil volume covered by roots was in erect forms and comprised 239.1 ± 13.8 cm (Table 1).

Table 1. Depth of penetration and mass of the first-year *Camphorosma lessingii* roots as a function of plant forms.

Root system indices	Plant forms (individuals)		
	1st type	2nd type	3rd type
Penetration depth, cm	149±7.7	155±6.4	189±8.7
Number of the main roots, pcs	12±2.6	8±3.3	6±1.8
Number of secondary roots, pcs	6±3.4	6±2.4	4±3.1
Total root length, cm	305.7±21.4	260.3±14.5	239.1±13.8
Root mass, g	7.9±2.6	6.5±2.1	6.2±1.3

These three plant forms found in populations of *Camphorosma lessingii* and their obvious differences in leafiness, fodder and seed productivity, as well as in number of generative shoots and buds of renewal formed, served as the basis for the selection of specimens of these forms and creation of a pasture variety of *Camphorosma lessingii*.

In the fall (October 28–29), the marked plants of the first type in each population of the collection nursery were mowed at a height of 7–10 cm (from the soil surface) by the method of mass (multiple) negative selection. In the spring, from mid-February, they were dug to a depth of 25 cm and planted in equal numbers in selection and conservation nurseries of the variety, with an area of 450–500 m². The same process was carried out in the control nurseries. Collected seeds of *Camphorosma lessingii* of type 1 (prostrate forms) individuals from the selection nurseries were sown in the nurseries of the competitive variety trial.

As a result of a comparative study, promising populations of the first type of plants were identified from the total number of available specimens of *Camphorosma lessingii*. According to the complex of ecological and biological indicators, a population of *Camphorosma lessingii* (K-309), which differed from other samples by high and stable year-to-year survival rate of seedlings and adult plants was singled out. There were also such features as drought tolerance, uniformity in height, seed maturation, and resistance to diseases and pests. This specimen was named Grace by us.

Two specimens of *Camphorosma lessingii* were taken for competitive variety trials. They were specimen (K-309) Grace and standard natural population (K-321) from Astrakhan Oblast (Privolzhsky district).

Due to high plant survival, drought tolerance and population uniformity in growth and bushiness, the selected specimen is capable of producing high forage yields, even in years with limited rainfall. As a result of stationary experiments laid in 2012 and 2015, the variety Grace, which was superior to the standard one in many biological properties and economically valuable traits that contributed to the formation of higher yields, turned out to be promising in two cycles of trials.

In the first cycle of trials, variety Grace outperformed the standard variety by 0.45 t/ha (21.2%) in green mass yield and by 0.33 t/ha (26.5%) in dry fodder mass on a three-year mean.

In the second cycle of trials, the same regularity was observed, namely, the variety Grace, bred by us, on average surpassed the initial population by 0.53 t/ha (17.6%) in green mass yield and by 0.71 t/ha in dry mass (34.9%) (Table 2).

Table 2. Yield of *Camphorosma lessingii* fodder mass in the competitive variety sowing trial in 2015 (second cycle).

Specimen	1st (2016) year			2nd (2017) year			3rd (2018) year		
	yield, t/ha	the differ ence with the stand ard speci men	LSD ₀₅	yield, t/ha	the differ ence with the stand ard speci men	LSD ₀₅	yield, t/ha	the differ ence with the stand ard speci men	LSD ₀₅
Green mass									
K-321 (standard)	1.98			2.85			2.61		
K-309 (Grace)	2.41	$\frac{0.43^*}{17.8^{**}}$	0.14	3.37	$\frac{0.52^*}{15.4^{**}}$	0.49	3.25	$\frac{0.64^*}{19.7^{**}}$	0.33
Drymass									
K-321 (standard)	0.83			1.69			1.31		
K-309 (Grace)	1.65	$\frac{6.2^*}{37.6^{**}}$	0.12	2.42	$\frac{0.73^*}{29.9^{**}}$	0.19	2.09	$\frac{0.78^*}{37.3^{**}}$	0.21

Note: *in numerator there is a difference with the standard specimen in t/ha, **in denominator there is the difference in %

The surpassing of the Grace variety in fodder yield over the standard variety is explained by the fact that the herbage of the variety was characterized by good uniformity, had up to 95% of prostrate, tall with good bushiness and foliage, individuals, while the standard variety had 60–65% of such individuals.

Thus, *Camphorosma lessingii* variety Grace in the conditions of arid regions of the Caspian Sea had high fodder productivity of 2.0 t/ha, as well as a fairly high seed yield (202 kg/ha).

4 Conclusion

As a result of the studies of structural-population forms organization of *Camphorosma lessingii*, it was established that during ontogenesis, when plants enter the budding phase, they begin to divide into three types of shrub forms. The first type is a prostrate form with weakly structured central shoot. The second type is a prostrate-climbing form, and the third type is an erect form with a well-defined central shoot. Among the identified three forms (types) of individuals, the first type proved to be the most ecologically stable and highly productive in terms of fodder and seed productivity (the prostrate forms with a weakly structured central shoot). This type of prostrate *Camphorosma lessingii* combines traits of xerophyte and halophyte, providing high tolerance to moisture deficit as well as tolerance to salt stress. Due to these properties, selected plants of prostrate *Camphorosma lessingii* in arid conditions of the Caspian semi-desert, with an annual sum of precipitation of 200–250 mm, form more than 2.0 t/ha of dry fodder mass, exceeding the standard variety by 23%.

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