The fodder shrub – *Halothamnus subaphyllus* (C.A. Mey.) Botsch.: reproductive biology and seed productivity in the culture

E Shamsutdinova\(^1\)* and Z Shamsutdinov\(^1\)

\(^1\) Federal Scientific Center for Crop Production and Agroecology, Lobnya, Russia

* E-mail: darplant@list.ru

**Abstract.** *Halothamnus subaphyllus* (C.A. Mey.) Botsch. – is a wild shrub, a potential fodder plant for introduction to culture in arid regions of Russia. This plant is well eaten by sheep, goats, horses, and camels. In bud stage, it contains 24.7% of protein, 2.7% of fat, 36.9% of nitrogen-free extractive substances, and 18.2% of fiber. Ecologically it is a haloxerophyte. *Halothamnus subaphyllus* is resistant to drought and tolerant to soil salinization. In introducing a new fodder plant into the culture, it is very essential to know the possibilities of its accelerated reproduction. Thus, we studied the reproductive biology and seed productivity of this plant in arid conditions. The initial blossom of *Halothamnus subaphyllus* is late May-mid-June. *Halothamnus subaphyllus* is a self-fertile plant. In the first year of life, this plant generates an average of 15.5 g of seeds per shrub. In the second and third years, seed productivity grows and reaches an average of 236.1 g per shrub, with 1 ha of 300-350 kg of seeds. Net reproduction of *Halothamnus subaphyllus* is 30-35. It means that the obtained seeds can be sown on 30-35 hectares of planted acreage.

1. Introduction

*Halothamnus subaphyllus* (C.A. Mey.) Botsch. – is a shrub from Chenopodiaceae, having stems covered with light grey bark. This is a highly branched plant, with branches mostly rejected, having a light green color, sometimes with a bluish tint [1]. Ecologically it is a haloxerophyte. *Halothamnus subaphyllus* is highly resistant to salt stress, air and soil drought [2].

Geographic range of *Halothamnus subaphyllus* covers various areas of the desert zone of Central Asia. It is found in the Aral–Caspian Depression, in the western Balkhash region, in the Karakums and Kyzylkums, where it grows on sand, clay and gravelly saline slopes, on the skirts of salt marshes [3].

*Halothamnus subaphyllus* is an extremely polymorphic species encountered in various ecological conditions of the desert zone [4]. There are three distinct ecotypes within this species. The northern one (sub sp. S. strangulata Iljin.) is of light green or bluish color being found in Kyzylkum, Balkhash region and Ferghana region. The second one is a shrub that grows on saline and rank soils (var. typica Drob.). This kind of plant is characterized by a small height, strongly spread branches and a dense spike-shaped inflorescence and wings, mostly lowered. The third type grows on sandy soils (var arenaria Drob.). This is a tall shrub form, the height of the plants reaches 1.5-2.0 m and has a looser spike-shaped inflorescence with almost straight or slightly lowered wings.

*Halothamnus subaphyllus* grows sparsely only on sandy substrates. Sometimes it forms thickets. *Halothamnus subaphyllus* is a very drought-resistant plant having a number of biological and economic features [5, 6].
The root system is of a universal type and, due to the physical and chemical characteristics of the soil, spreads to different depths (3-6 m) depending on the soil profile. The ability of *Halothamnus subaphyllus* to develop an aggressive root system, use moisture and nutrients of deep soil layers provides a long vegetation period during torrid and hot summer [7].

The eaten parts of *Halothamnus subaphyllus* are shoots, young and partially last year's twigs, as well as fruits that are well eaten in spring, summer and winter, better – in autumn. *Halothamnus subaphyllus* as a fodder contains 24.7% of protein, 2.7% of fat, 36.9% of nitrogen-free extractive substances, and 18.2% of fiber. Highly nutritious fodder: 100 kg of air-dry fodder mass contains 48-50 fodder units [7].

Good fodder qualities, excellent high resistance to salt stress and drought resistance, necessitate the study of the features of reproductive biology, seed productivity, as well as the development of methods for introducing *Halothamnus subaphyllus* into the culture [6, 8].

2. Materials and methods

Pilot work was carried out in the semi-desert zone of the Republic of Kalmykia (Ermeli village). Natural conditions are droughty. The summer is hot, the temperature of July is +25-27°C, maximum +38-42°C. The sum of active temperatures is 3300-3450°C. Winter is snowless with strong winds. The frost-free period lasts 160-170 days. Year – on-year precipitation averages 200-270 mm. The soils of the plot are brown, semi-desert, saline-saline. The ecology of flowering and pollination of *Halothamnus subaphyllus* was considered by the method of A. N. Ponomarev [9], the seed productivity was determined according to the Guidelines for the mobilization… [10].

3. Results and discussion

3.1. Reproductive biology

*Halothamnus subaphyllus* it begins to grow in the third decade of March, and at the end of April, small, barely visible buds appear in the axils of the leaves. The buds are teardrop-shaped, green, are with a thickened part on young growing shoots, located alternately in a spiral. As the shoots grow, new buds are formed (Table 1).

| Indicators | Shrub category | | | | |
|---|---|---|---|---|
| Number of buds per shrub | small | middle | big |
| Including on shoots of the 1st order | 552 | 1252 | 3254 |
| | 100 | 100 | 100 |
| 2nd order | 5.2 | 23 | 11.6 |
| | 9.4 | 1.8 | 3.6 |
| 3rd order | 261 | 233 | 1600 |
| | 47.3 | 18.6 | 49.2 |
| 4th order | 239 | 858 | 1515 |
| | 43.3 | 68.5 | 46.5 |
| 4th order | 138 | 23 | |
| | 11.1 | 0.7 | |

Note: in the numerator – absolute numbers, in the denominator – %, as in Table 3 and Table 6

The largest number of them (over 50%) is formed from the beginning of May to the end of the first decade of June. After that, the formation rate of new buds goes down and by the beginning of October is no more than 4-5% per month of the total number of buds. The duration of the budding phase of...
*Halothamnus subaphyllus* is 90-100 days.

During the growing season, shoots of the first, second, third, fourth, and sometimes fifth orders are formed on the shrubs of *Halothamnus subaphyllus*.

The majority of buds are laid on shoots of the 2nd and 3rd orders, less-on the youngest (4th and 5th orders) and old (1st order) shoots (Table 1).

The number of buds on the shrub grows with age (Table 2).

**Table 2.** Number of buds on *Halothamnus subaphyllus* (C.A. Mey.) Botsch. shrubs of different ages.

| Vegetation year | Number of buds on the shrub, pc |
|-----------------|---------------------------------|
| First           | 938                             |
| Second          | 11665                           |
| Third           | 19697                           |

As a rule, the beginning of flowering of *Halothamnus subaphyllus* (C.A. Mey.) Botsch. falls on the end of May – the beginning of June, mass – on the middle of June. Older shrubs starts the flowering phase approximately 10 days earlier than the young ones. The flowers are solitary, collected in panicle-shaped inflorescences, androgyne, sessile. The flower-cup consists of three fleshy green sepalas, pulled together by a film. Five stamens are arranged freely in a circular pattern, attached directly at the base of the pistil. There is only one bilobed pestle. Laminae are curved at the end in the form of scoops. During the day of flowering, the perianth leaves diverge and between them, an opening appears at the top of the flower, from which the anthers are pushed out, being on the anther filaments and having a bright red color. At the end of flowering, the anthers fall off, laminae of the stigma slightly darken and converge. Opening at the top of the flower is nearly closed and only the remains of the anther filaments may be seen from it.

According to the results of experiments on the isolation of shrubs, *Halothamnus subaphyllus* is a self-pollinated plant (Table 3). Data obtained indicate that the isolation of a whole and half of *Halothamnus subaphyllus* shrub resulted in the development of full-fledged fruits. At the same time, the isolated shrubs and isolated parts of the shrubs formed the same number of fruits as the open (free) and parts of the shrub.

**Table 3.** Fruit blossom in *Halothamnus subaphyllus* (C.A. Mey.) Botsch.

| Experience version | Number of initiated buds | Number of full-fledged fruits |
|--------------------|--------------------------|------------------------------|
| Without whole shrub isolation | 7.04±0.44              | 5.63±0.21                    |
|                    | 100                      | 80.1                         |
| Without half-shrub isolation | 2.97±0.52              | 2.70±0.19                    |
|                    | 100                      | 91.0                         |
| In case of whole shrub isolation | 4.10±0.51              | 3.67±0.15                    |
|                    | 100                      | 89.5                         |
| In case of half-shrub isolation | 1.50±0.14              | 1.30±0.12                    |
|                    | 100                      | 86.6                         |

Our observations have revealed that the dehiscence period of one flower is quite extended. It is 8-9 hours and falls mainly (60%) in the daytime, from 11 a.m to 2 p.m. From the opening of the flower to its complete flowering takes an average of 21-22 hours.

Flowering, that began at the end of May, ends mainly (90%) in the third decade of August. The flowering phase is extended and is 80-90 days in the culture. In the second decade of August, the
rudiments of winglets begin to appear on the perianth, which progressively (until the second decade of October) grow and turn light yellow. By mid-October, they get a shiny brownish-brown color. The fruits are large, the weight of 1000 pieces of air-dry fruits varies between 10.0-16.4 g, sometimes reaching 20.0 g.

Fruit of *Halothamnus subaphyllus* can be divided according to the degree of maturity (Table 4) for the following phases: 1) conditionally embryonic, which lasts from fertilization of the ovaries to the appearance of winglets; 2) formation of winglets, which is subdivided into three subphases: appearance, staining and browning of winglets; 3) full ripeness of fruits, which can also be divided into two subphases: drying and falling of fruits.

Table 4. Dynamics of fruit maturation of *Halothamnus subaphyllus* (C.A. Mey.) Botsch. within culture conditions.

| Phenological phase | 1st year of vegetation | 2nd year of vegetation | 3rd year of vegetation |
|-------------------|------------------------|------------------------|------------------------|
| Embryonic         | begin 25.VII          | end 20.VIII            | begin 27.VII           | end 15.VIII            | begin 18.VIII          | end 12.VIII |
| Formation of winglets: appearance | 20.VIII | 12.IX | 15.VIII | 7.IX | 12.VIII | 3.IX |
| Staining          | begin 12.IX           | end 2.X                | begin 7.IX             | end 29.IX              | begin 3.IX             | end 27.IX |
| Browning          | begin 2.X             | end 14.X              | begin 29.IX            | end 12.X               | begin 27.IX            | end 10.X |
| Full ripeness of fruits: drying falling | begin 14.X | end 30.X | begin 12.X | end 28.X | begin 10.X | end 28.X |
|                   | 30.X                  | 10.XI                 | 28.X                   | 30.XI                 | 28.X                   | 30.XI |

3.2. Seed productivity

Seed productivity results of *Halothamnus subaphyllus* in the culture conditions considered in plants of different ages are given in Table 5.

In the first year of life *Halothamnus subaphyllus* bears fruit and forms an average of 15.5 g of seeds per plant. In the second and third years, its seed productivity grows and is in the third year of life-236.1 g per shrub.

Table 5. Seed productivity of *Halothamnus subaphyllus* depending on the age.

| Shrub age | Average weight of seeds per shrub, g | Average number of seeds per shrub, thousand pcs. | Average weight of 1000 pieces of seeds, g |
|-----------|---------------------------------------|--------------------------------------------------|------------------------------------------|
| Annual    | 15.5±2.37                             | 1.1±0.17                                         | 13.8±0.03                                |
| Biannual  | 36.6±9.34                             | 2.9±0.75                                         | 12.4±0.81                                |
| Triennial | 236.1±33.37                           | 19.3±2.73                                        | 12.2±0.81                                |

Our research has demonstrated that not all flowers form fruit. During the spring-early summer period, when the conditions are most favorable for the growth and development of shrubs and semishrubs, the maximum number of buds on the shrubs is initiated. Yet not all flowers are realized in full-fledged fruits. As a rule, most of them in the summer, during the xerothermic season, dry up and fall off.

Under natural growing conditions, *Halothamnus subaphyllus* forms only 41.8% of the fruits from the number of buds (Table 6). The number of formed full-fledged fruits in plants of the first year of vegetation in the culture appeared to be close to those growing in natural conditions. The number of
fruits increases with age. Thus, in the second and third years of the growing season, it reached 68.8-94.0% of the number of buds formed. The highest percentage of death of buds and flowers is found in the phases of budding (from 0.9 to 15.2%), flowering (from 20.2 to 40.3%), fruit formation (from 0.7 to 12.0%).

Table 6. Potential and actual seed productivity of *Halothamnus subaphyllus* (C.A. Mey.) Botsch. depending on age.

| Shrub age | Total number of initiated buds | Formed full-fledged fruits | Dry flowers | Dry buds | Unripe fruit |
|-----------|--------------------------------|-----------------------------|-------------|----------|-------------|
| Annual    | 11665                          | 8024                        | 2358        | 683      | 600         |
| 100       | 938                            | 84.5                        | 40.3        | 15.2     | ___________ |
| Biannual  | 19697                          | 18509                       | 861         | 173      | 150         |
| Triennial | 491                            | 205                         | 167         | 60       | 59          |
| Perennial | 100                            | 94.0                        | 4.4         | 0.9      | 0.7         |

Consequently, it is essential to develop a set of agrotechnical and biological methods contributing to an improvement in the seed productivity of *Halothamnus subaphyllus*.

Shrub *Halothamnus subaphyllus* in the culture grows quickly, develops and bears fruit in the first year of life. In the culture conditions its seed productivity is quite high, which rises in the second and third years and reaches 236.1 g per shrub.

4. Conclusion

*Halothamnus subaphyllus* (C.A. Mey.) Botsch. flowers are isolated, in spikelike inflorescences, collected by a panicle. Perianth glabrous, exceeding the bracteoles from ovate-oblong, widely scarious-edged with dull leaves, developing fruit. From the middle they are translucent, reniform, rounded or inversely eggplant and mostly set behind each other, colorless or pink wings with slightly lowered edges.

Structure and mechanism of flowers dehiscence of *Halothamnus subaphyllus* attests to their adaptability to self-pollination. The fact of self-pollination is proved by our experiments on the isolation of shrubs. From the beginning of flower dehiscence of *Halothamnus subaphyllus* to complete flowering is an average of 21-22 hours. Beginning of *Halothamnus subaphyllus* flowering is at the end of May – beginning of June, mass – in mid-June. Seasonal rhythm of *Halothamnus subaphyllus* flowering in the culture is 80-90 days.

In the culture conditions *Halothamnus subaphyllus* enters the fruiting phase in the first year of life and forms full-fledged seeds (fruits) that ripen in October. The fruits are large, the weight of 1000 pieces of dry fruits varies between 10-16 g. The highest seed productivity of *Halothamnus subaphyllus* is found at the age of three, reaching an average of 236.1 g of seeds per shrub. At the age of 2-3 years, *Halothamnus subaphyllus* gives 300-350 kg/ha of seeds on experimental crops.

Acknowledgement

This research was supported by a grant from the Russian Science Foundation (project No. 19-16-00114).

References

[1] Nechaeva N, Vasilevskaya V and Antonova K 1973 *Plant life forms of the Karakum Desert* (Moscow: Nauka Publ.) p 244

[2] Akzhigitova N 1982 *Halophilic vegetation of Central Asia and its indicative properties* (Tashkent: Fan Publ.) p 190
[3] Botanical geography of Kazakhstan and Middle Asia (desert region) 2003 (Saint Petersburg: Boston-Spectr Publ.) p 424
[4] Dzyubenko N and Soskov Yu 2014 Genetic resources of Kochia prostrata (L.) Schrad (Saint Petersburg: VIR Publ.) p 336
[5] Pyankov V and Mokronosov A 1991 Problemy osvoeniya pustyn 3(4) pp 161-170
[6] Shamsutdinov Z, Savchenko I and Shamsutdinov N 2000 Halophytes of Russia, their environmental assessment and usage ecological evaluation and management (Moscow: Edel-M Publ.) p 399
[7] Shamsutdinov N, Shamsutdinova E, Shamsutdinov Z and Orlovsky N 2017 Herald of the Russian Academy of Sciences 87(1) pp 1-10
[8] Shamsutdinov N, Savchenko I, Shamsutdinova E, Orlovsky N, Shamsutdinov Z and Kaminov Yu 2018 Russian Journal of Ecology 49(6) pp 475-483
[9] Ponomarev A 1954 Bot. zhurn. 39(5) pp 706-720
[10] Guidelines for the mobilization of plant resources and the introduction of arid fodder plants 2000 (Moscow: Russian Agricultural Academy Publ.) p 82