Ecological aspects and analysis of ecotypes of kochia prostrate (Kochia prostrata (L.) Schrad)

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Abstract. Over the past few decades, the state of the land in the arid zones of Russia is developing extremely unfavorably due to irrational pasture use. One of the ways to solve the problem is the development of halophytes in culture to create different varieties (as fodder) and restore saline soils. Halophytes (galos – salt, phyton – plant) is a special group of ecologically and physiologically adapted plant species that are able to maximize their potential in conditions of severe salinity. Halophytes – being useful as fodder, medicinal and oil-bearing plants – have a powerful environment-forming function and the ability to desalt saline soils. One of such halophytes is kochia prostrate. This is a pasture high-protein forage crop that has a number of nutritional properties, is well eaten by many animal species (in particular, cattle and small cattle), and is also promising for use in phytomelioration on natural pastures in arid regions of Eurasia, Africa and America. Fodder based on kochia prostrate is well balanced regarding amino acid composition (lysine, methionine, threonine, etc.), thereby is an excellent fattening feed. Therefore, it is important to understand, from the point of view of selection, on what type of soil will Kochia grow favorably and give the maximum yield for creating new varieties. This article presents the results of comparing the feed and seed productivity of three ecotypes of the xerogalophytic fodder half-shrub of kochia prostrate (Kochia prostrata (L.) Schrad).

1. Introduction

Kochia prostrata (L.) Schrad – kochia prostrate, halophyte – is a shrub from the goosefoot family (Chenopodiaceae), 35–165 cm tall with yellow, green or red shoots raised up, slightly wavy, occasionally with medium-length hairs.

Kochia is widely distributed over the vast territory of Eurasia. It grows in the lower reaches of the Don, Middle and Lower Volga, in Dagestan, in the Ciscaucasia, Southern and Eastern Transcaucasia, the Aral-Caspian lowland, foothill Turkmenistan, in Central Asia, in the desert and semi-desert zones of Kazakhstan [4].

Research on the creation of varieties of kochia prostrate is conducted not only in Russia, but also in many other foreign countries (USA, Iran, China, Canada, etc.). At present, only in the USA, over 18 different forms of kochia prostrate are isolated [5–7].

Kochia prostrate is a unique plant and has every chance of becoming the most promising in biology, genetics, medicine, as well as in many other sectors of the economy (rural, forest and fish), as it contains a high percentage of ecdysteroids, hormonal substances that are involved in the management of homeostasis and serve as superhormonal regulators of most body functions [8].

Kochia is not only environmentally flexible; it also gives an impressive yield with great nutritional value [9, 10].
2. Materials and Methods

Studies of kochia prostrate compared with the productivity of the best samples of different ecological and geographical origin were carried out in the period from 2008 to 2016 in the arid zone of the North-Western Caspian Sea, in the Yashkul region of the Republic of Kalmykia, on the basis of the joint Experimental station of the Federal Williams Research of Forage Production and Agroecology and All-Russian Research Institute of Hydrotechnical Reclamation named after A.N. Kostyakov.

The research area is characterized by a sharply continental climate. Summer is hot, dry, the sum of active temperatures is over 3600 °C. The average July temperature is +25–26 °C, often rising to +43 °C. The coldest month of the year is January, with an average temperature of −8–10 °C.

The average annual precipitation decreases from north to south from 280 to 200 mm. During the warm period, the amount of precipitation (April-October) is 160 mm, while the maximum amount of precipitation (about a third of the annual amount) falls on April-June.

The soils are brown, medium loamy in terms of particle size distribution with weakly expressed genetic horizons. The average groundwater level is in the range of 15–20 m.

In the research process, 53 samples of kochia prostrate were collected in different ecological and geographical regions of Central Asia and Russia, of which 6 promising samples were selected for the subsequent creation of the variety. Collection and breeding nurseries were established in 2005 and 2009. The accounting area of the plots was 10.5 m².

3. Results

Currently, there are a small number of varieties capable of growing most successfully in the arid conditions of the North-Western Caspian on various types of soils and substrate.

The creation of source material for introduction into the culture in the arid regions of the North-Western Caspian region involves selective improvement of the species based on a comprehensive ecological and biological study of intraspecific diversity. The work purpose was to identify the most adaptive material, various ecological and geographical forms were involved in research. Important in the study of this problem was to compare, as accurately as possible, different types of ecotypes of different ecological and geographical origin.

The work also was to identify the most promising samples and later develop varieties that can successfully grow on different soils and give the maximum yield of seeds and dry fodder mass.

The biology of flowering kochia prostrate in the arid zones of Russia has not been studied. Kochia has rather small and inconspicuous flowers with a green cup-shaped perianth. Kochia flowers of stony ecotype are protrogenic, i.e. stigmas bloom long (from 7 to 20 days) before the stamens emerge; the latter dry out by the time of pollination.

Flowers are planted mainly in the middle and upper part of the generative shoot. Depending on the environmental conditions of the year, 3 to 35 or more flowers are formed in the glomerulus.

The flower consists of five stamens of the same size; sometimes it can be found with four, very rarely with six stamens, located in a circle right at the base of the pestle, separately from each other. Anther filaments are white and rounded in cross section. The color of the anthers is different, there are both light yellow and cream. Pestle is single and has no column. The stigma is bilobate, rarely trilobate with a large number of papillae on the surface. The ovary is on top. On the perianth near the fruits, form rounded, sometimes triangular pterygoid appendages, giving the fruit the shape of a small star. The fruit is a single-seed nut.

Kochia prostrate is cross-wind-pollinated plant. Kochia prostrate lacks self-pollination, this is evidenced by the fact that by the time the flower is opened and the stamens are dusted, the stigma of the pistil is already dry (kochia of sandy and clay ecotype). The kochia prostrate of a stony ecotype can be attributed to cross-wind-pollinated plants, due to the fact that individuals carry only female flowers that last until the fall.

Features of flowering. Kochia flowers of three ecotypes begin to open in the morning at a temperature of 17.1–34 °C and a relative humidity of 17–83 %. The maximum number of flowers bloom by 9–10 a.m., a little less flowers bloom after 6 p.m. Blooming kochia prostrate has a two-peaked type and
can be attributed to morning or afternoon and evening. In favorable and average years of humidification, Kochia, which is stretched in culture, blooms in the first year of life. As a result of studying the daily course of flowering, it was found that in early August, the flowers of all three ecotypes of Kochia prostrate begin to open at a temperature of 22–25 °C and a relative humidity of 25–40 % (in the morning). Dusting begins 20–30 minutes after the stamens emerge and lasts for 1–1.5 hours, depending on the strength of the wind. In windy, cool weather, the flowers of the Kochia prostrate do not open.

**Daily rhythm of flowering.** The observations were made on collection crops of 2009 on five-year-old plants of stone, clay and sand ecotypes. Calculations of blossoming flowers were carried out from 6 a.m. every hour on August 5, 12 and 19, 2016 for all three ecotypes.

On August 5, observations showed the following. By 9 a.m., the maximum of blooming Kochia prostrate flowers (stony ecotype) was detected on sample K-76 (53) and later, by 10 a.m., the maximum number of blooming flowers was on sample K-202 (45) at a temperature of 28.8 °C and relative humidity of 35 %.

On August 12, in the course of observations, we found that the maximum of blossoming flowers was also observed in sample K-76 (75 flowers) and K-202 (61 flowers) at a temperature of 27.8 °C and a relative humidity of 37 %. By 10 a.m. for these samples, the maximum number was 41 and 35 blossoming flowers, respectively, at a temperature of 28.6 °C and a relative humidity of 30 %.

The observations that took place on August 19 showed the following: the largest number of blossoming flowers was also observed in sample K-76 (72 flowers), in sample K-202 (69 flowers) at 10 a.m. at a temperature of 28.2 °C and a relative humidity of 35 %.

On the example of a clay ecotype on August 5, we see the following: the largest number of blossoming flowers at 9 a.m. was observed in sample K-85 (46), in sample K-212 (50) at a temperature of 26.7 °C and a relative humidity of 45 %.

On August 12, the samples demonstrated the following: the largest number of blossoming flowers was also observed for sample K-85 (62), for K-202 (56) at 9 a.m. at a temperature of 25.8 °C and a relative humidity of 40 %.

On August 19, the maximum of blossoming flowers was observed at 9 a.m. in samples K-85 (72 flowers), at a temperature of 24.2 °C and a relative humidity of 45 %.

As for the sandy ecotype, here we see that the most favorable conditions for the flowering of Kochia prostrate is the temperature of 24–27 °C and relative humidity of 45 %.

On August 5, we see the following: the largest number of blossoming flowers at 9 a.m. was observed in sample K-226 (68) at a temperature of 25.6 °C and a relative humidity of 45 %. At 10 a.m. it was demonstrated by sample K-92 (72) at a temperature of 26.7 °C and a relative humidity of 41 %.

On August 12, the largest number of blossoming flowers at 9 a.m. was observed in sample K-226 (87) at a temperature of 23.4 °C and a relative humidity of 40 %. At 10 a.m. it was also shown by K-226 sample (85 flowers) at a temperature of 25.7 °C and a relative humidity of 38 %.

On August 19, the largest number of blossoming flowers at 9 a.m. was observed for sample K-226 (102 flowers) at a temperature of 22.4 °C and a relative humidity of 55 %.

The following differences can be found among all three ecotypes of Kochia prostrate: the longest flowering phase was observed in the stony ecotype (60 days), followed by a clay ecotype, the phase of which was 44 days which is slightly inferior to the clay sand ecotype with (40 days).

It is also worth noting that the stone ecotype also begins to bloom earlier than anyone else, about 7–9 days earlier than the sandy ecotype and 5–7 days earlier than the clay ecotype. The maximum number of flower openings was noted in ecotypes differently; for example, for stony ecotype it is 75 flowers (sample K-76) on August 12, for clay ecotype 72 flowers (sample K-85) on August 19, for sand ecotype 102 flowers (sample K-226) on August 19. However, the peak of flower opening in most ecotypes of Kochia prostrate falls at 9 a.m. The most comfortable conditions for this are a temperature of 25–27 °C and a relative humidity of 34–40 %.

**Seasonal flowering rhythm.** Observations and flower counting for the season were carried out on 3 ecotypes of Kochia prostrate: stony, clay and sand on 3 medium bushes. Counting the number of appearing flowers was carried out every 7 days three times a day: at 8, 12 and 19 o’clock.
Collected in different living conditions, the populations of kochia prostrate are divided into 2 groups: early flowering and late flowering. Late flowering (dark green inflorescences), bloom 7–9 days later than early flowering (light green inflorescences). In the inflorescences of early and late flowering plants, the number of flowers is different. So, for example, the average generative shoot of an early flowering plant forms 60–80 flowers, and in late flowering plants the number is 40–60. During the seasonal flowering rhythm, all three ecotypes of kochia prostrate (stony, clay and sand) initially show a gradual increase in the number of flowers with a peak, followed by a slow decrease in the number of flowers, after which the flowering stops.

Starting from the middle of the flowering period, the greatest appearance of flowers is noted. The largest number of flowers in kochia prostrate is formed in the period from mid-August to early September, after which a gradual decrease in flowers on the bushes of kochia is observed.

The entire population of kochia prostrate blooms a little over a month, this is due to the different timing of its blooming and the nature of the duration of flowering of individual plants.

As a result of observations of the seasonal flowering rhythm of all three ecotypes of kochia prostrate, we found that the flowering of the sandy ecotype ends a little earlier in comparison with other ecotypes.

Table 1. Feed and seed productivity of promising samples of three ecotypes of kochia prostrate in a 2009 breeding nursery, t/ha

| Catalog number | Average for 3 years (2014–2016) | Seed productivity, [kg/ha] | Forage crop yield [t/ha] |
|----------------|--------------------------------|---------------------------|--------------------------|
|                |                                | Stone ecotype             | Green                   | Dry          |
| K-76 (Alians)  |                                | 219.1                     | 5.4                     | 2.6          |
| K-202          |                                | 187.2                     | 4.1                     | 1.9          |
| K-85 (Surius)  |                                | 193.2                     | 4.7                     | 2.2          |
| K-212          |                                | 180.9                     | 4.0                     | 1.8          |
| K-92 (St)      |                                | 170.8                     | 3.4                     | 1.5          |
| K-226          |                                | 203.3                     | 4.6                     | 2.1          |

As a result of studies in the 2009 breeding nursery, during the period from 2014 to 2016, it was found that all three ecotypes of kochia prostrate (stony, clay and sand) showed good yield, according to two main research parameters (seed and fodder productivity).

The highest-yielding ecotype turned out to be stone on: samples K-76 and K-202 (over 2.5 t/ha of dry feed mass and up to 230 kg/ha of seeds).

A comparative analysis of the data on the yield of fodder mass showed that during the three years of observation, the K-76 sample stood out with maximum productivity, forming, depending on the age, up to 2.7 t/ha of dry fodder mass, and significantly exceeded in this parameter, as the K-92 standard, and another promising sample K-85 (Table 1).

The clay ecotype K-85 also exceeded the standard for fodder and seed productivity, albeit slightly. It is worth noting that all three ecotypes have excellent adaptation properties that allow them to grow fruitfully and provide the ultimate yield of dry fodder mass in extremely hot conditions.

The stone (K-76 sample) and clay ecotypes (K-85 sample) showed the best results in basic research parameters; sandy ecotype (K-202 sample) showed the worst results.

Taking into account the seed productivity of the samples in the breeding nursery revealed the advantages of the K-76 sample: 219.1 kg/ha on average over three years.

After analyzing the data of Table 2 on the density of standing, we can conclude that the survival of all three ecotypes is at a high level, the death of plants occurs mainly in the winter, but not significantly.
Table 2. Standing density, height and number of shoots of three ecotypes of kochia prostrate in a 2009 breeding nursery of sowing, thousand units/ha

| Catalog number | Average for 3 years (2014–2016) | Standing density [t/ha] | Height [cm] | Number of shoots on the middle bush [pcs.] |
|----------------|----------------------------------|------------------------|-------------|------------------------------------------|
|                |                                  | Stone ecotype          |             |                                          |
| K-76 (Alians)  |                                  | 59.03                  | 80.8        | 73.3                                     | 40.3                                      |
| K-202          |                                  | 61.3                   | 81.9        | 70                                       | 47.3                                      |
| K-85 (Sirius)  |                                  | 52.7                   | 76.2        | 66                                       | 47.6                                      |
| K-212          |                                  | 50.9                   | 72.9        | 67.3                                     | 45.3                                      |
| Sand ecotype   |                                  |                        |             |                                          |
| K-92 (St)      |                                  | 52.6                   | 72.8        | 56.3                                     | 36                                        |
| K-226          |                                  | 59.3                   | 81.3        | 58                                       | 40                                        |

As a rule, active growth begins in mid-May and continues until the end of August. The height of the samples in 2016 was from 55 to 79 cm. The samples K-76 (79 cm) of stone ecotype and K-85 (73 cm) of clay ecotype turned out to be tall, these same samples were distinguished by the best survival.

The height and number of shoots on one bush for all three ecotypes varied from year to year within small limits.

4. Conclusions

As a result of studying the daily course of flowering, it was found that kochia is a two-peak plant: morning, or midday, and evening. At the beginning of August, the flowers of the three kochia ecotypes begin to open at a temperature of 22–25 °C and a relative humidity of 25–40 %. The maximum number of flowers blooms by 9–10 a.m.; in the evening, the flowers open less. The seasonal flowering rhythm lasts more than a month, starting from the third decade of July until the end of the second decade of September.

Thus, the analysis of these studies showed that in the breeding nursery, the K-76 sample of stone ecotype and the K-85 sample of clay ecotype, were characterized by high fodder and seed productivity, as well as earlier flowering (sand ecotype (sample K-226) was insignificantly inferior). All the samples were distinguished by high survivability and drought tolerance, increased bushiness, evenness of the grass stand, and abundant foliage.

As a result of studying promising samples, the numbers were identified that possess sufficient biological and economic indicators for selection as a source material, and are capable of increasing adaptive properties, productivity and energy value.

The selected samples based on the biotypic selection method allowed obtaining the source material for creating new varieties.

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