Morphological traits of *Ferula foetida* (Bunge) Regel. in the desert of Mangystau

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Abstract. The morphological traits of growth in aboveground and underground organs of *Ferula foetida* found in Mangystau, depending on the age and place habitat of the plant, have been studied for the first time. A very high variability (up to 54-98%) of the great majority of the morphological traits, except for sizes of leaves of the 1st rosette and length of the main root before branching (12-26%), is noted for all the studied populations, which is explained by almost proportional participation in formation of composition of populations with species of different age. Meanwhile, variation of isomers in both, aboveground and underground parts within each age-grade declines by several-fold (<10%) and remains stable regardless of the living environment.

1 Introduction

Ferula foetida Bunge (Regel) is a medicinal and edible plant [1, 2]. The herb is used in medicine in the East, which is defined by its rich composition of bioactive substances accumulated mainly in the underground organs and in fruits. Composition of the gum resins include mainly resin (up to 50-70%), gum (up to 35-40%) and ether oils (up to 10%), as well as vanillin, free ferulic acid and other components. Ferula is a good forage plant and is edible for people as well – leaves and shoots of some types of *F.foetida* are consumed in fresh, cooked, fried, pickled forms and as a spice [3-5].

In arid Mangyshlak, asafetida is very common in the Eastern Mangyshlak geobotanical zone [6], in the southern part of the Mangyshlak peninsula, in the Northern Ustyurt on argillaceous plains, on fixed and semi-fixed sands of central and southern desert areas. *F.foetida* is confined to sandy and rubble-clayey soil in deserts. Commonly, this specimen forms large populations acting as a dominant. Over 20 populations of *F.foetida* overtake large areas and reproduce very well in natural conditions annually. Its morphological traits in different populations are diverse which is related with the growing environment.

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The objective of this survey was the study of morphological traits of *F.foetida* in natural habitats in the Mangystau region.

2 Materials and methods

2.1 Herbal raw material

During expeditions in 2015-2018, 6 multiple-aged (from 1 to 7 years) natural associations of *F.foetida* located in sandy massifs of Tuyesu and Karynzharyk, western and southern parts of Tynymbai Shoky upland, Karaadyr tract, on the northern shoulder of the Burma mountain, were selected for studying the morphological traits.

2.2 Study methods

The examined populations with participation of *F.foetida* were exposed to geobotanical descriptions in accordance with the standard practices [7-9], characteristics of soil coverage based on the selected soil and analyses of its salinity and aquatic-physical indicators [10]. During the studies of asafetida morphology, measurements of 6 aboveground and 10 underground growth indicators (Table 1) were made across the whole age interval – from one to seven years. The selected material was processed with the use of mathematical statistics and the application Stat Graphics Centurion XVI.I (2011).

2.3 Description of territories

Tuyesu sands are located in the southern part of Mangyshlak peninsula, where *F.foetida* participates in saxaul-ferula-sagebrush-psammophytic-shrubby associations. *Haloxylon aphyllum* acts as the dominant in the association, *F.foetida* is a co-dominant. The generic projective coverage (GPC) is 50-65%. The soil is sandy and loamy, mainly non-saline or sub-saline, supplied with shallow fresh water. The groundwater depth is 3.5(5.0)-41 m.
Tynymbai Shoky upland is also assigned to the southern regions of Mangyshlak peninsula. The *F.foetida* population occurs within saxaul-ferula and sedge-white-ground-sagebrush-ferula associations. The soil significantly varies in its mechanical composition and salinity. It is sandy to the depth of 30 cm, light loamy from 30 to 50 cm, and middle loamy in the interval from 50 to 100 cm. The salinity of soil from the surface to the depth of 50 cm is low, average in the interval of 50-80 cm; and high on depth of 80-100 cm. Water content is extremely low; the plants draw water from precipitation and shallow ground water of different salinity.
Karynzharyk sands are located in the southern-western part of the Karynzharyk hollow, in the southern-karynzharyk region of Mangystau. The soil is sandy and loamy, non-saline across the whole genetic profile. Karynzharyk sands are poorly flooded or arid; the plants draw water from precipitation and shallow ground water of different salinity. Ground water occurs in individual small areas at the depth available for desert plants. Thickets of *F.foetida* are widely common within kemrud-sagebrush-ferula-grasses-saxaul and sedge-kemrud-sagebrush-thirst-quenching-saxaul associations. GPC is 50-65%.

Table 1. Morphological traits of the aboveground and underground parts of *F.foetida* in natural populations of Mangystau (average data by age, cm)

Morphological traits, cm	Tuyesu sands	Western oart of Tynymbai Shoky	Southern part og Tynymbai Shoky	Karyn-zharyk sands	Karaadyr tract	Northern shoulder of the Burma mountain

Aboveground part						
Plant height	49.4±3.2 37.5%	36.0±1.7 26.6%	39.4±2.4 35.7%	43.8±3.3 4,3.4%	44.1±3.2 41.3%	42.3±4.1 44.5%
Stem diameter	14.7±1.4 57.1%	15.4±2.6 97.9%	19.2±2,4 72.4%	15.8±0.8 27.9%	14.9±1.0 37.8%	10.9±1.4 57.8%
Number of basal outlets	4.0±0.4 54.0%	4.2±0.5 62.4%	4,0±0,4 55.6%	4.0±0.4 56.1%	3.9±0.3 49.5%	4.3±0.5 57.6%
The length of leaves of the 1st rosette	12.8±0.8 34.5%	10.2±0.7 38.8%	11,4±0,6 33.1%	9.3±0.4 11.8%	13.3±1.7 49.4%	10.4±0.9 39.7%
The width of leaves of the 1st rosette	4.6±0.3 36.5%	3.5±0.4 59.5%	3,4±0,2 40.4%	3.1±0.1 25.9%	3.3±0.1 18.2%	3.7±0.3 36.6%
Leaf biomass, g	329.2±28.6 86.1%	222.4±23.0 91.2%	376,0±7,1 87.1%	449.6±41.9 91.9%	481.0±42.4 86.4%	142.9±19.2 95.9%
Underground part						
Number of branches	4.0±0.3 41.9%	4.0±0.3 45.5%	3.7±0.4 56.4%	3.9±0.4 52.9%	4.0±0.3 47.7%	3.6±0.5 62.1%
Depth of root system	91.6±7.8 50.1%	109.3±8.3 43.5%	112.8±7.6 39.0%	106.1±7.6 41.3%	109.1±8.7 46.0%	111.1±16.4 67.6%
Main root length before branching	34.8±2.9 37.8%	34.99±3.0 38.6%	39.0±3.2 37.9%	38.7±2.8 30.9%	45.1±2.7 24.1%	30.1±1.8 17.7%
The diameter of the root neck	17.4±2.7 89.5%	12.9±1.3 58.1%	13.5±1.3 56.5%	14.2±1.1 44.3%	15.0±1.2 47.5%	12.2±1.8 69.2%
The diameter of the middle part of the main root	18.0±1.1 35.9%	15.92±1.2 42.0%	17.7±1.2 40.8%	21.1±1.7 46.4%	18.9±1.8 54.0%	13.8±1.4 47.6%
The diameter of the end of the main root	2.4±0.2 46.3%	2.8±0.3 64.3%	2.1±0.2 49.2%	2.4±0.2 58.7%	2.8±0.3 67.1%	2.8±0.4 64.4%
The number of roots	4.8±0.48; 53.1%	5.6±0.9 89.8%	4.4±0.4 48.1%	4.6±0.4 54.5%	4.3±0.5 61.5%	3.7±0.4 51.2%
Length of roots	14.3±0.7; 29.5%	16.7±0.9 30.3%	17.2±0.8 28.3%	15.5±0.7 25.3%	13.0±1.2 51.9%	16.8±3.0 81.4%
The length of the roots of the 1st branch	59.7±5.6; 54.9%	55.7±5.0 52.0%	55.8±4.0 42.3%	55.1±5.4 56.7%	54.0±5.7 60.8%	65.6±8.0 55.7%
Weight of roots, kg	2.5±0.047; 90.8%	1.0± 0.245; 89.0%	1.69± 0.36; 93.2%	1.0±0.163; 92.7%	1.0±0.17; 93.8%	0.5±0.144; 95.1%

F.foetida has been identified on loamy massifs in kalligonum-shrubby associations in the vicinity of Karaadyr tract (8-10 km southward the Karynzharyk sands). The soil there is non-saline from surface down to 80 cm, with low salinity within the interval of 80-100 cm. Water supply to the natural populations is very low; the plants draw water only from precipitation. Water permeability of the soil is high.

In the area of Burma hill, associations with participation of *F.foetida* were identified on low gullied slopes with sub-saline semi-consolidated clay-loamy soil. Thinned thirst-quenching-gurgan-sagebrush-grasses populations are specific for this area with participation of shrubs – goat's wheat and shrubby bindweed. The area has low water content. The soil is non-saline from the surface down to 50 cm; with average salinity in the interval of 50-80 cm and low salinity in the interval of 80-100 cm. Water permeability of soil is average.

3 Results and discussion

F.foetida is a perennial monocarpic plant which annually generates bottom leaf rosette and increases the root volume. The plant develops most actively during its first 3-4 years. During the 5-7 years of vegetation, the plant enters the reproductive period; it flowers and bears

only once. Nutriments accumulate in the root during the whole life cycle and then are used for formation of the stem with reproductive organs, after the root completely perishes [11]. The results of the surveys demonstrated vast range of variability: height of the plants (20-89 cm) and root depth (34-155 cm) in Tuyesu sands; 17-69 cm and 44-162 cm in Tynymbai Shoky uplands; 19-72 cm and 35-142 cm in Karynzharyk sands respectively. By the average height (Table 1), it is noted that the plant grows most intensively in the populations in Tuyesu sands (63.57 cm), slower in Karynzharyk sands (51.44 cm). The shortest plants grow in loamy massifs of Tynymbai Shoky uplands (49.20 cm). The ratio between the associations in the depth of roots is a bit different: Tynymbai Shoky upland (122.07 cm), Karynzharyk sands (102.83 cm) and Tuyesu sands (92.66 cm). The difference in height and root depth between the populations is statistically significant at 5% level of significance. It has been established that if the correlation ratio between the morphology data within one population is in average 0.8-0.9, then in whole for all the studied associations it decreases to 0.5-0.6 due to influence of a number of soil and reclamation factors: water availability, mechanical composition, salinity, alkalinity. The most intensive growth of roots in Tynynbai Shoky upland is due to adaptive reaction to deeper ground water and favorable impact of the ratio between the upper soft sand and lower middle loamy layers of the soil. Weight of the underground part of *F.foetida* takes up to до 40-85% of the total raw phytomass of the plants (Table 1), where its largest share is steady in the habitats with fixed sandy and loamy soil of mild rockiness and deep ground water – Tuyesu sands and southern part of Tynybai Shoky upland. Not always strong development of aboveground phytomass can guarantee more intensive formation of the root system. This is influenced by adaptive reaction of *F.foetida* to formation of a stronger succulent underground structure for accumulating moist and its rational use through a weaker assimilative mechanism of the plants according to the specific habitat conditions. During entering into the reproductive period (from 5-6 years), a gradual growth inhibition is observed regardless of soil and reclamation conditions in the natural associations. Just the opposite tendency has been identified for the weight of roots, whose formation is the most active from 4 years to the end of life cycle of the plant. The most actively *F.foetida* develops during the first 3-4 years in the majority of its morphological traits including height of the plant and depth of the roots. Starting from 5-6 years, gradual growth inhibition, and even growth arrest, occurs regardless of edaphic conditions in the natural populations. Just the opposite tendency has been identified for the weight of roots, whose formation is the most active from 4 years to the end of life cycle of the plant. It has been identified that regardless of the habitat conditions, *F.foetida* annually forms one bottom leaf rosette and one branching of the root. A very high variability (up to 54-98%) of the great majority of biometric parameters, except for sizes of leaves of the 1st rosette and length of the main root before branching (12-26%), is noted for all the studied populations, which is explained by almost proportional participation in formation of composition of populations of different age.

Meanwhile, variation of isomers in both, aboveground and underground parts within each age-grade declines by several-fold (<10%) and remains stable regardless of the living environment. Just the opposite tendency has been identified for the weight of roots, whose formation is the most active from 4 years to the end of life cycle of the plant.

4 Conslusion

Following the surveys conducted in the arid conditions of Mangystau, it has been established that in the majority of cases the difference among the main growth indicators of *F.foetida* is morphologically similar. It confirms the assignment to the strictly defined ecological niche with sandy and strongly stony soils. Specimen of different age take almost proportional participation in formation of the composition of *F.foetida* populations, which

explains very high variability (up to 54-98%) of isomers of growth, although variability of morphological traits inside each age group significantly decreases (<10%) and maintains at constant level for the whole profile of habitat conditions in Mangystau region. It has been established that up to 40-85% of total phytomass falls on the weight of underground part of the most medicine-valuable *F.foetida*, and its maximal specific weight is observed in the habitat conditions with fixed sandy and loamy soil of average rockiness and with deep ground waters. Thereby, strong development of aboveground part of *F.foetida* does not always ensure intensive formation of root rhizosphere, since the adaptive reaction takes place through formation of a succulent root structure for accumulating moist and its rational evaporation via a weaker leaf system.

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