CHAPTER 5

SPINY ATRAPHAXIS (*Atraphaxis spinosa* L.)

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1- INTRODUCTION

Atraphaxis spinosa L. is one of the 48 species in the Atraphaxis genus in the Polygonaceae family. This species is a perennial shrub-shaped plant that has a strong root system, is resistant to salty and arid soils, and can grow in nutrient-poor soils (Bentham and Hooker, 1880; Pavlov, 1970; Lovelius, 1979; Tavakkoli et al., 2013; Yurtseva et al., 2016; Temel et al., 2017; RBG, 2023). The plant sheds its leaves in winter and forms shoots and leaves again in spring (Karakuş and Keskin, 2018). Shoots and leaves of *Atraphaxis spinosa* are grazed by camels, sheep and goats (Shahriary et al., 2012; Rakhimova and Rakhimova, 2022). It also serves as a shelter for wild animals (Zadeh and Kharasmi, 2013).

In geographies where extreme ecological conditions are experienced, there is an intense forage deficit, especially in the summer and autumn seasons. However, halophyte and xerophyte species, especially shrubs, that can adapt to these conditions and maintain their greenness and productivity for a long time, have an important alternative feed potential. One of these shrub species is *Atraphaxis spinosa*. The nutritional content of *Atraphaxis spinosa* significantly meets the needs of animals. Crude protein ratio varies between 5.9% and 12.7% depending on the development periods throughout the year. Neutral detergent fiber varies between 44.4% and 68.2%, and acid detergent fiber varies between 27.1% and 47.1% (Karakuş and Keskin, 2018). Although the macro and micro (nitrogen, potassium, calcium, phosphorus, sodium, copper, magnesium, manganese, iron, zinc) nutritional contents of *Atraphaxis spinosa* vary significantly according to the development periods of the plant, it significantly meets the needs of animals (Keskin, 2018). However, *Atraphaxis spinosa* can accumulate high amounts of Cr and Pb (Sakizadeh et al., 2018). *Atraphaxis spinosa* lowers the pH of the soil where it grows and causes more calcium, potassium and magnesium accumulation (Karakuş and Keskin, 2018). Since *Atraphaxis spinosa* seeds collected in natural environments have a high rate of dormancy, when the plant is grown with seeds, dormancy breaking (Giberallic acid or cold and warm stratification) processes must be done on the seeds and sown (Temel et al., 2023).

The roots of *Atraphaxis* contain flavonoids, above soil parts of plant contain alkaloids, and the leaves contain tannins. Compounds found in the *Atraphaxis spinosa* plant are afzelin, N-trans-p-coumaroyldopamine, N-trans-

p-coumaroyl-3',4'-dihydroxyphenylethylamine, N-trans-feruloyldopamine, N-trans-feruloyl-3',4'-dihydroxyphenylethylamine, (-)-catechin, quercetin, quercetin-3-methyl ether, (-)-fisetinidol, 5-deoxykaempferol, butine, β-sitosterol glucoside,3-O-b-D-glucuronide-600-methyl ester, myricitrin, quercetin-3- O-b-D-glucuronide, 2-(b-D-glucopyranosyloxy, 200-galloyl-quercetin-3-O-b-D-glucuronide, methyl gallate, -4-hydroxy-6-methoxyacetophenone, a-linolenic acid, lucidulactone A, gallic acid, loliolide, luteolin 7-methyl ester, 4' -α-D-glucofuranoside 7-luteolin 7-methyl ester, 4'-β-D-glucofuranosyl-6-β-D-glucopyranoside 7-O-luteolin methyl ester, 3-β-L-rhamnopyranoside 3,8,3', 3,8,3', 4'-tetrahydroxyflavone and 4'-tetrahydroxyflavone (El-Gamal et al., 1994; Wang et al., 2018; Umbetova et al., 2020). With these determined features, it seems that the plant is suitable for use as medicinal raw material.

It is an important plant in preventing erosion and protecting natural resources (soil and water) because it covers a large area on the soil surface and has a strong root system (Karakuş and Keskin, 2017).

2. SYSTEMATIC AND MORPHOLOGY

Atraphaxis is a genus of flowering plants (Angiosperms) in the family Polygonaceae, containing approximately 48 species (Table 1).

The genus Atraphaxis is widespread in parts of Southwest Asia, Southern Siberia, Southeastern Europe, North Africa, Mongolia, and China. *Atraphaxis spinosa* species are found in countries such as Afghanistan, Russia, China, Egypt, Greece, Mongolia, Iran, Iraq, Kazakhstan, Turkmenistan, Kyrgyzstan, Lebanon, Syria, Saudi Arabia, Manchuria, Mongolia, Pakistan, Palestine, Turkey, Tajikistan, Ukraine and Uzbekistan (Bentham and Hooker, 1880; Pavlov, 1970; Lovelius, 1979; Cullen, 1967; Brandbyge, 1993; Webb, 1993; Rechinger and Schiman-Czeika, 1968; Bao and Grabovskaya-Borodina, 2003; Schuster et al., 2011; Yurtseva ve ark., 2016; Temel et al., 2017; Baasanmunkh et al. 2022; RBG, 2023). *Atraphaxis spinosa* has 3 synonyms (*Atraphaxis afghanica* Meisn., *Atraphaxis calvertii* Boiss. and *Tragopyrum spinosum* (L.) C.Presl).

The *Atraphaxis spinosa* plant, which is found in the form of a dwarf shrub, sheds its leaves in winter and its branches are usually thorny. *Atraphaxis*

spinosa has a plant height between 1.05 and 1.45 m and covers an area of 2.95 to 5.55 m in length and 2.80 to 4.46 m in width (Figure 1). Wood branches are hairless and whitish. The leaves are oval or rounded and have a length of 0.6 to 1.3 cm. The flowers are white and pink, 0.8 mm in diameter. Its fruit is triangular or flat. It is a hermaphrodite plant with female and male organs in the same flower (Güven, 1997; Tavakkoli et al., 2015; Karakuş, 2016; Wang et al., 2018; Erşen Bak and Cesur, 2021; IDS, 2023). The fruit is in the form of achene and there is one seed in each fruit (Dammer, 1893; Roth 1977; Ronse De Craene et al., 2000). *Atraphaxis spinosa* is annual shoots diameter 1.5-3.0 mm, annual shoots lignified and spiny, surface of annual shoot glabrous, petiole length 1-2 mm, perianth surface glabrous, achene surface smooth or smooth-pitted (Yurtseva et al., 2017).

Table 1: Species in the genus *Atraphaxis* (Tavakkoli et al., 2015; Yurtseva et al., 2017; Anonymous, 2023)

A. angustifolia	*A. ariana*	*A. spinosa*
A. intricata	*A. avenia*	*A. decipiens*
A. arida	*A. atraphaxiformis*	*A. teretifolia*
A. irtyschensis	*A. billardierei*	*A. selengensis*
A. aucheri	*A. salicornioides*	*A. pyrifolia*
A. kamelinii	*A. kermanica*	*A. manshurica*
A. badghysi	*A. bracteata*	*A. rodinii*
A. karataviensis	*A. caucasica*	*A. grandiflora*
A. binaludensis	*A. ledebourii*	*A. popovii*
A. botuliformis	*A. khajeh-jamali*	*A. frutescens*
A. radkanensis	*A. daghestanica*	*A. dumosa*
A. canescens	*A. kuvaevii*	*A. pungens*
A. kopetdagensis	*A. laetevirens*	*A. suaedifolia*
A. compacta	*A. laetevirens*	*A. seravschanica*
A. schischkinii	*A. muschketowii*	*A. toktogulica*
A. davurica	*A. macrocarpa*	*A. virgata*

Atraphaxis spinosa remains dormant for 120 days from mid-November to mid-March in regions with cold winters. It begins to develop shoots in mid-

March and completes all phenological observations by mid-November. The plant's leaf formation continues for 240 days between mid-March and early November (Table 2) (Temel and Keskin, 2019). *Atraphaxis spinosa* can produce flowers and fruits twice a year during its development period. The first flowering occurs in April-May and the second flowering occurs in August. Parallel to the flowering state, the fruit period also occurs twice a year (Li et al. 2010, 2011; Temel and Keskin, 2019; Kostina and Yurtseva, 2021). Figures of the *Atraphaxis spinosa* plant showing the dormant, shoot and leaf periods, flowering period and fruit periods are given in Figures 1, 2, 3 and 4, respectively (Temel and Keskin, 2019).



Figure 1. Plant height, length and width measurements of *Atraphaxis spinosa* (Karakuş, 2016)

Table 2. Phenological observations of *Atraphaxis spinosa* (Temel and Keskin, 2019)

	Phenological Observations Examined										
Months	**Dp**	**Sb**	**Sp**	**Lb**	**Lp**	**Bb**	**Bp**	**Pb**	**Pp**	**Pm**	**Dp**
Early March	+										
Mid March		+	+	+	+						
End of March			+		+						
Early April			+		+						
Mid April			+		+						
End of April			+		+	+	+				
Early May			+		+		+				
Mid May			+		+		+				
End of May			+		+		+				
Early June			+		+		+				
Mid June			+		+		+	+	+	+	
End of June			+		+				+	+	
Early July			+		+				+	+	
Mid July			+		+				+	+	
End of July			+		+				+	+	
Early August			+		+						
Mid August			+		+						
End of August			+		+	+	+				
Early September			+		+		+				
Mid September			+		+		+				
End of September			+		+		+	+	+	+	
Early October			+		+		+		+	+	
Mid October					+		+		+	+	
End of October					+		+		+	+	
Early November					+				+	+	
Mid November											+

Fenolojik Dönem Kısaltmaları		
Dp: Dormant period	**Dp:** Dormant period	**Dp:** Dormant period
Sb: Shoot beginning	**Sb:** Shoot beginning	**Sb:** Shoot beginning
Sp: Shoot perion	**Sp:** Shoot perion	**Sp:** Shoot perion
Lb: leaf beginning	**Lb:** leaf beginning	**Lb:** leaf beginning



Figure 1. Dormant period ((Temel and Keskin, 2019)



Figure 2. Shoot and leaf period ((Temel and Keskin, 2019)



Figure 3. Flowering period (Temel and Keskin, 2019)



Figure 4. Fruit period (Temel and Keskin, 2019)

3. ADAPTATION

Many shrub and woody species growing under natural conditions have high tolerance to drought, thanks to their deep and strong root systems, and can grow in areas where cultivated plants cannot grow. *Atraphaxis spinosa* is a xeromorphic shrub that grows in desert steppes, mountain shrub communities, salty, gravelly and stony surfaces, sand dunes, calcareous soils, nutrient-poor

soils, at altitudes up to 1600 m (Lovelius, 1978; Perevolotsky et al., 1989; Kapustina, 2001; Bondarenko et al., 2009; Wang et al., 2018).

Species with thick exocarps are common mainly in the mountainous regions of Central Asia, and species with thin exocarps are common in semi-deserts and steppes of Eurasia. Fruit color associated with amount of phenolics in exocarp cells may be related to differences in the timing of seed germination. Species with light brown fruits are common, while those with dark or black fruits are mostly local endemics (Yurtseva et al., 2022).

Vein elements and number of veins are important features in resistance to arid areas (Baas et al., 1983; Carlquist 1988). *Atraphaxis spinosa*'s short wood branches, narrow fibers, and high number of veins increase its resistance to arid areas compared to other Atraphaxis species and many plants (Erşen Bak and Cesur, 2021). In places where the annual rainfall is low, the *Atraphaxis spinosa* plant continues to develop (Rakhimova and Rakhimova, 2022). The layer on the outer surface of atraphaxis seeds protects the seeds against mechanical damage, accelerates the germination of seeds by retaining water, and protects the seeds against pathogens (Lattanzio et al., 2006, 2008).

There is a significant amount of dormancy in *Atraphaxis spinosa* seeds collected in natural environments. Germination rates of *Atraphaxis spinosa* seeds subjected to different temperatures (10, 15, 20, 25, 20/10, 20/15, 25/10, 25/15 °C) vary between 0.0-22.6%. While the seeds do not germinate at 10 °C, 22.6% of the seeds germinate when the germination test is performed at a variable temperature of 25/15 °C. *Atraphaxis spinosa* seeds have 77.4% dormancy. If the *Atraphaxis spinosa* seeds collected in the natural environment are sown and used to create new areas, the seeds should be sown considering that only one out of 5 seeds will germinate. Dormancy breaking studies were also carried out on *Atraphaxis spinosa* seeds, where dormancy is very high. In order to eliminate dormancy in *Atraphaxis spinosa* seeds, 12 dormancy breaking applications (Hydro-priming, matrix priming, potassium nitrate, gibberellic acid, mechanical scarification, Chemical (sulphuric acid) scarification, cold stratification, warm stratification, cold + warm stratification, warm + cold stratification, soaking in hot water and soaking in cold water) were made. When 250 ppm gibberallic acid was applied to the seeds, 77% of the seeds germinated. When *Atraphaxis spinosa* seeds were cold stratified at +5 °C for only 4 weeks or cold stratified at +5 °C for 4 weeks followed by warm

stratified at 20 °C for 2 weeks, it was observed that the dormancy in the seeds was completely removed and 100% of the seeds germinated (Temel et al., 2023). If the seeds obtained in the early stages are kept in high temperature and dry conditions for a while, it is seen that the seeds germinate immediately (Li et al., 2010, 2011).

Atraphaxis spinosa affects many properties of the soil in which it grows. Examining the soil samples taken from the inner and outer crown parts of the plant, it was seen that the soil inside the crown was more acidic. At the same time, the calcium, potassium and magnesium content of the soil inside the crown is high. It also has an effect on the mineral contents of the different depths of the soil where the plant grows. For example, calcium and potassium accumulate in abundance at a soil depth of 20-40 cm, while phosphorus and sodium accumulate in excess at a depth of 40-60 cm (Karakuş and Keskin, 2017). This species contributes significantly to the development of other species in the environment due to its positive contribution to the structure of the soil.

4. YIELD AND QUALITY

In regions with dry summers, plants in meadows areas cannot continue to grow in summer and autumn and dry out, and the roughage available per unit meadows area decreases significantly. Drought-resistant shrub species are a source of fodder for animals in the summer and autumn periods when herbaceous species dry out and their nutritional value decreases (Temel and Tan, 2011; Tan and Temel, 2012). Shrub plants can produce forage rich in energy, minerals, vitamins and nutrients for animals (Ghazanfar et al., 2011; Tan and Temel, 2012). In cases where there are no palatable species in the environment, *Atraphaxis spinosa*, a thorny species, is grazed by animals (Shahriary et al., 2012). Young shoots of *Atraphaxis spinosa* are consumed by camels in spring and partly in summer. Sheep and goats eat the leaves (Rakhimova and Rakhimova, 2022). Since the growth rate of the plant is low, feed efficiency is low, especially in the spring season (Rakhimova and Rakhimova, 2022).

Atraphaxis spinosa is a perennial shrub plant that grows up to 1.45 m tall, covers a large area up to 5.55 m length and up to 4.46 m wide (Karakuş, 2016). In regions with cold winters, it continues to develop leaves and shoots

for 240 days, from mid-March to early November (Temel and Keskin, 2019). Due to this feature of the *Atraphaxis spinosa* species, grazing animals in areas where this plant is commonly found can provide feed for a long time.

In a study in which the changes in the monthly nutritional content of the *Atraphaxis spinosa* shrub were determined according to its development periods throughout the year; acid detergent fiber, crude protein, neutral detergent fiber, dry matter digestibility, acid detergent lignin, digestible energy, dry matter intake, dry matter rate and relative feed value values were determined in the range 27.13-47.13%, 5.93-12.79%, 44.41-68.28%, 52.18-67.75%, 3.62-14.46%, 2.50-3.17 Mcal kg^{-1}, 1.75-2.71%, 27.33-70.66% and 71.46-142.32, respectively. Although the feed quality of the plant decreased significantly due to increased maturation, the lowest crude protein content was observed to be 5.93%. While feed values are high between mid-March and July, when the plant begins to develop, there are decreases in feed values from July until mid-November, when the plant enters the dormant period (Karakuş and Keskin, 2018). There are significant decreases in feed value with the advancement of development in many other shrub plants (Parissi et al., 2005; Gonzalez-Andres and Ceresuela, 1998; Papachristou et al., 2005; Kamalak, 2006; Ataşoğlu et al., 2010; Oktay and Temel, 2015; Temel, 2019; Dökülgen and Temel, 2019).

The shoot + leaf parts of the *Atraphaxis spinosa* plant are consumed by animals. Although the macro and micro mineral contents of shoots + leaves vary significantly according to their development periods, they significantly meet the mineral needs of animals. According to the development periods during the year, phosphorus, nitrogen, potassium, magnesium, calcium, sodium, copper, iron, zinc and manganese contents of *Atraphaxis spinosa* vary between 0.43-0.98%, 0.98-1.27%, 1.08-1.46%, 0.27-0.46%, 0.86-1.17%, 0.12-0.99%, 0.86-2.66 ppm, 112.0-344.7 ppm, 25.3-42,4 ppm and 44.1-64.9 ppm. The nitrogen content of the plant is high in May and October. As maturity progresses, phosphorus, potassium, sodium and zinc contents decrease, while manganese and iron contents increase. There is no significant change in the calcium and magnesium contents of the shoots and leaves of the plant depending on the development periods (Keskin, 2018). *Atraphaxis spinosa* plant is a species with a high potential to accumulate Cr and Pb (Sakizadeh et al., 2018).

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