



## Ecology of *Festuca karatavica*, a promising tussock grass for restoration of alpine rangelands

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### Abstract

Alpine ecosystems are characterized by extreme environmental conditions, including cold temperatures, low rainfall, poor soils, and high winds, which severely constrain plant growth and establishment. Despite these challenges, keystone plant species native to these habitats play a vital role in ecosystem restoration and conservation. One such species is *Festuca karatavica* (Bunge), a tussock grass native to alpine regions of northern Iran and Central Asia, found at elevations ranging from 1800 to 3100 m.a.s.l. This species is particularly valuable as a source of livestock fodder and for its contributions to soil and water conservation. In this study, we investigated the phenology, nutrient content, and ecological preferences of *F. karatavica* along an altitudinal gradient in its natural habitat on Shirbad Summit, northeast Iran. We also analyzed associated plant species diversity and richness, as well as soil physical and chemical properties. The phenological cycle of *F. karatavica* begins in early April and concludes with seed shedding by September, with seasonal variations influenced by annual rainfall. Crude protein content, acid detergent fiber (ADF), and neutral detergent fiber (NDF) were highest during early growth stages but declined over the growing season. Its seeds germinate easily without dormancy, suggesting strong regenerative potential. Soil conditions vary across the altitudinal gradient, with sandy loam textures and the highest pH (7.4) and electrical conductivity (EC) observed at the summit, decreasing at lower elevations. Species diversity peaked at mid-elevation (2831 m.a.s.l.), while species richness and evenness were highest at higher (3050 m.a.s.l.) and lower (2720 m.a.s.l.) elevations, respectively. The most favorable habitat for *F. karatavica* was identified at mid-elevation, where optimal soil nutrients (N, P, and organic C) and mycorrhizal associations supported its growth. Growth at higher altitudes is constrained by poor soil conditions and harsh climatic factors, whereas competition, intensive grazing, and erosion limit its success at lower altitudes.

### Introduction

*Festuca karatavica* (Bunge), is a perennial native grass. It grows in alpine habitats and provides a reliable source of fodder for livestock and wildlife. It is also important for soil and water conservation in alpine ecosystems with harsh climates. Intense livestock grazing and possible climate change effects have led to

the replacement of *F. karatavica* by *F. sclerophylla*, a closely related species whose distribution range extends through Alborz and central Zagros toward north-eastern Turkey and Caucasian mountains (Memariani and Arjmandi, 2013). According to the extent of its occurrence and its very peculiar habitats, which are highly sensitive to climate change, *F. karatavica* is evaluated as an endangered (EN, B1ab (ii, iii)) species in Iran (Memariani and Arjmandi, 2013). In this study, we investigated the ecological conditions and phenology of *F. karatavica* at Shirbad, the tallest summit of the Binalud Mountain range in northeast Iran.

*F. karatavica* (Bunge) B. Fedtsch. Turkest. (Fig1). It is densely tufted. Culms 50-100 (-140) cm, glabrous, at base tightly enveloped by brownish butt sheaths. Leaf sheaths glabrous on surface; ligule an eciliate membrane, truncate, 1.5-5 mm long (Memariani and Arjmandi, 2013).



Fig 1. *Festuca karatavica* in Flora of Khorasanica

### Phytogeography and ecology

The general distribution of this Irano-Turanian species is from western Tian Shan, southwestern Pamir-Alay, to northeastern and northcentral parts of Afghanistan, and the newly recorded specimens from Binalud Mountains extend the distribution range of *F. karatavica* more westward to NE Iran. Ecologically, it grows in higher mountain and alpine areas on stony slopes, rocks, and screes. In the Binalud mountain ranges, its habitat is usually on metamorphic schistose rocks at high elevations between 1800 to 3000 m. From westward, in calcareous rocky slopes of the North Khorassan Province (Aladagh and Salook and Shah-Jahan Mts.) (Memariani and Arjmandi, 2013).

### Methodology

The investigated area was determined by the priority of the presence of *F. karatavica*; in three altitudes, the first elevation was 3050 meters with the coordinates of 36°17'35' North and 59°05'40' East, the second is located at the height of 2831 meters of 36°17'27'N and 59°05'49.49' E. The third altitude was at 2720 meters of 36°17'20.6' N and 59 ° 05'3.40' E.

In each elevation, three transects were established, in which 5 quadrats of one square meter were placed randomly. The abundance and canopy cover of *F. karatavica* and all other plant species were measured within quadrats.

Forage quality was monitored by measuring crude protein (nitrogen), ADF (Acid Detergent Fiber), NDF (Neutral Detergent Fiber) and DMD (Digestible Dry Matter). The formula provided by Oddy *et al.*, 1983 was used:  $DMD\%^{10} = 83/56 - 0/824 \quad ADF\% + 2/626 \quad N\%$

Metabolic energy was calculated after calculating the digestibility percentage of dry matter from the equation provided by "Deutsches Institut für Normung" (DIN):  $ME^2 (MJ/Kg) = 0.17 DMD\% - 2$

The SPSS software was used to analyze the data. The nutritive values of plant samples from different elevations were compared at different phenological stages using one-way analysis of variation.

To determine the phenological stages, 10 individuals of *F. karatavica* were selected from each elevation class. Phenological growth stages were recorded every 20 days from April to July in 2015 and 2016.

### Results and discussion

Forage quality changes were compared according to NDF, ADF and protein (Fig 2). The amount of NDF increased ( $P < 0.00001$ ) by increasing plant phenological stages from early emergence to seed shedding. Consistent with other studies on native grasses of Iran (Arzani et al., 2004), the highest amount of NDF was in the seed ripening stage and the lowest amount was in the early growth season, conversely protein content was reduced from the early growth towards the seed ripening stage. The critical limit of protein is shown as a line, which is defined as the critical level that is needed to keep the grazing livestock alive.

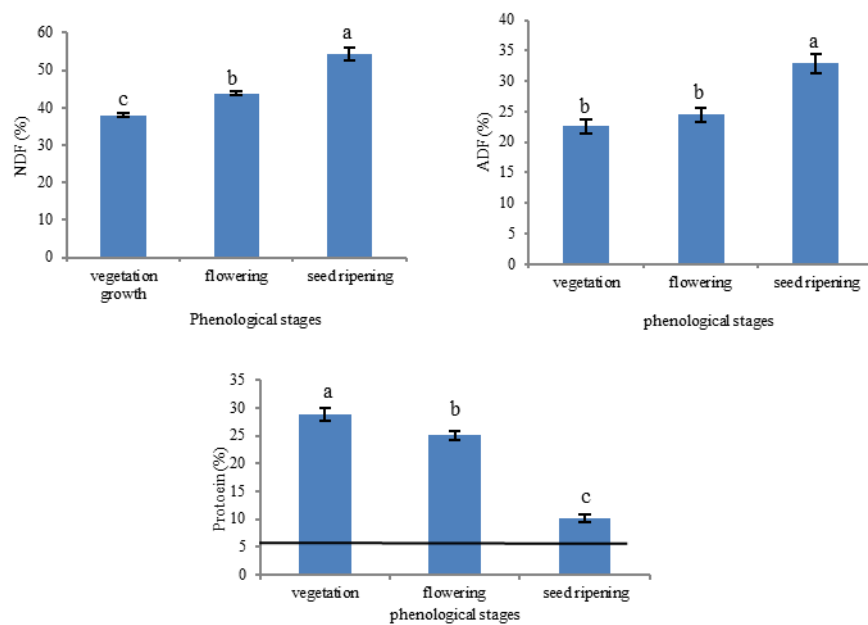


Fig 2. Effect of Phenological stages on Nutrition qualification factors

The results of the plant phenology in 2015 showed that growth initiation in high-altitude were from the end of April to the mid-May. Phenological stages commenced a week earlier in the mid and low elevations than the summit site. A dry spring in 2016 led to an earlier growth stages as compared to those we had recorded for 2015 as a normal year (Fig3).

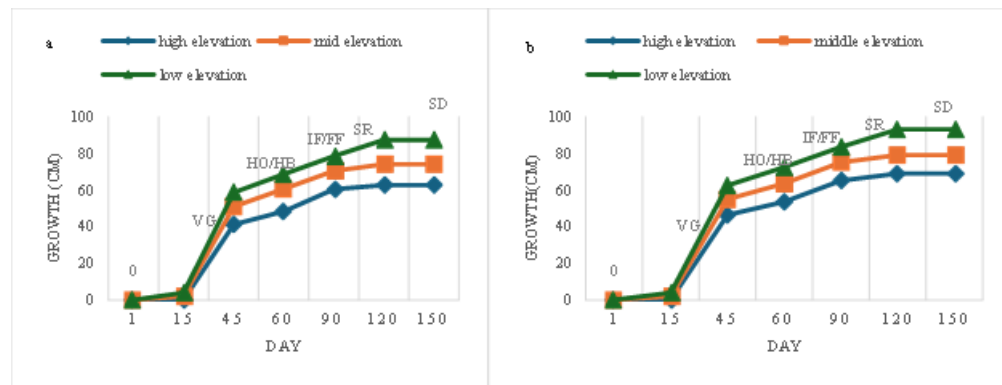


Fig 3. Phenological stages in different elevation in a normal (2015) and a dry (2016) year.

By increasing the elevation, mycorrhiza spore counts and the inoculation rate were reduced, similar to the changes observed for soil moisture (Fig4).

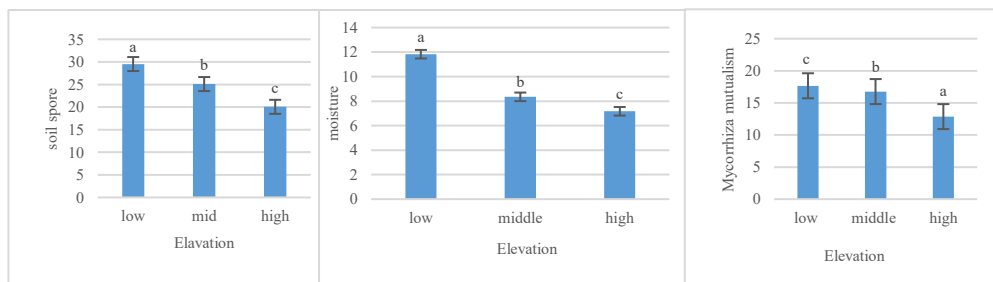


Fig 4. Changes in Spore, Moisture and Mycorrhiza in different states of study elevation.

The soil texture in each altitudinal habitat was loamy. Silt, nitrogen, and phosphorous levels were higher at lower altitudes, whereas clay and EC levels were higher at higher elevation. (Table1).

Table 1. Soil properties in three elevation

Index	Low Elevation	Mid Elevation	High Elevation
Sand (%)	43.75±0.79	57.5±2.62	46.75 <sup>a</sup> ±1.75
Silt (%)	40.25±0.74	28.25±1.89	31.5±1.80
Clay (%)	16±0.35	14.25±1.35	20.75±1.43
Texture	loamy	loamy	loamy
EC (µs/cm)	1826±0.35	1824.50±1.35	1823.25±1.63
Ca (meq/lit)	140.5±0.55	124.5±1.01	108±1.25
N (ppm)	2129±0.93	2074.75±1.27	2021±1.75
pH	7.40±0.004	7.36±0.03	7.32±0.03
Organic matter (%)	2.82±.58	2.77±0.21	2.95±0.21
Phosphorus (ppm)	32.65±0.68	28.32±0.69	24.02±0.92

The habitats of *F. karatavica* differed in plant community indices, with mid-altitude habitats showing the highest species diversity and richness but the lowest evenness compared to high- and low-altitude habitats (Table 2).

Table 2. Biodiversity indexes in different studied altitude

Elevation Index	Index	Low	Middle	High
Diversity	Shannon-Wiener	2.490	2.695	2.518
	Simpson	0.819	0.831	0.792
	Hill N2(	4.964	5.577	4.640
	Hill N1(	5.65	6.50	5.76
	Brillouin	2.125	2.431	2.274
Evenness	Camargo	0.525	0.573	0.536
	Simpson revers	0.682	0.608	0.549
	Modified Knee	0.227	0.165	0.187
Richness	Number of species	8	10	9
	Jack Knife	12.4	15.3	10.8

### Conclusion

In this study, we provided detailed insights into the phenological growth stages, nutritive value, soil characteristics, mycorrhizal symbiosis, and plant community indices of *Festuca karatavika*, a keystone species native to the alpine ecosystems of northeast Iran. Our findings shed light on the environmental constraints limiting the distribution of this species and contributing to its classification as endangered. At lower elevations, higher soil organic matter and nutrient levels likely promote greater mycorrhizal symbiosis. However, more intense livestock grazing and competition from invasive species like *Eremurus olgae* may reduce its abundance in these areas. Conversely, harsh microhabitat conditions, such as low soil moisture, poor nutrient availability, and extreme climate, may account for its low abundance at higher

elevations. Our results suggest that the mid-altitude zone of Shirbad Mountain provides the most suitable habitat for *Festuca karatavika*, offering a balance between protection from harsh upper-elevation conditions and reduced grazing pressure.

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