



Herbage yield and quality of five native species of Milkvetch (*Astragalus spp.*) under rain-fed conditions in Iran

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Abstract:

The role of different species of *Astragalus* in soil erosion prevention, genetic storage, species diversity, improving of soil fertility by fixing atmospheric nitrogen, and finally, the production of good quality forage is of great importance. This research aimed to investigate the quality and quantity of five herbaceous milkvetch species (*Astragalus brevidens* Freyn & Sint., *Astragalus vegetus* Bunge, *Astragalus cyclophyllon* Beck, *Astragalus effusus* Bunge, and *Astragalus brachyodontus* Boiss.) under rain-fed conditions in Damavand, Iran. The seeds of each species were collected from their natural habitats and sown in the field using a completely randomized block design with three replications in 2017. Data were collected for Dry Matter (DM) yield, canopy cover, plant height, stem number, and seed yield at the seeding stage in 2019. For quality traits, forage samples were taken in three phenological stages (vegetative, flowering, and seeding) in 2020, and the traits of Crude Protein (CP), Dry Matter Digestibility (DMD), Water-Soluble Carbohydrates (WSC), Crude Fiber (CF), acid Detergent Fiber (ADF), Neutral Detergent Fiber (NDF), total Ash, and Metabolisable Energy (ME) were estimated using Near Infrared Spectroscopy (NIR). The results showed that there was no significant difference among the species for DM yield, but the higher and lower values (2233 and 1853 kg/ha) were obtained in *A. effusus* and *A. cyclophyllon*, respectively. For morphological traits, there were significant differences among the species, and the higher values of canopy cover area (7050 cm²), plant height (70 cm), stem number (38.33/plant), and seed yield (411 kg/ha) were obtained in *A. vegetus*, *A. brevidens*, *A. effusus*, and *A. brevidens*, respectively. Also, our findings indicate that the amount of CP, DMD, WSC, Ash, and ME was higher in the vegetative and flowering stages than that in the seeding stage. The total mean of all the studied species with values of 15.76% and 12.16% for CP, 66.11 and 63.64 for DMD, and 9.24 and 8.81 for ME were obtained in the vegetative and flowering stages, respectively, which classify them as desirable forage species. Additionally, all the studied species are suitable for grazing by livestock in both growth stages from spring up to the middle summer seasons. Based on the findings, milkvetch has the attributes of a desirable forage species. It was concluded that *A. effusus* and *A. cyclophyllon* were the superior species for both yield and quality traits among the studied species.

Keywords: Nutritional value; Forage; Semi steppe rangelands; Phenological stage; Milkvetch

Introduction

Rangelands play a crucial role in producing forage and feeding livestock. The quality and quantity of forage, along

with its nutrients, significantly affect the growth and development of livestock during the grazing season (Melo et al., 2022). To ensure that rangelands are sustainably developed

and that satisfactory livestock growth and reproduction are achieved, range managers must understand the nutritional values of forages. Investigating forage characteristics is necessary for determining grazing capacity (Asaadi and Khoshnood Yazdi, 2011; Amiri, 2012).

Forages vary greatly in terms of quantity and feeding value (Bagheri Rad et al., 2015; Moore et al., 2020). The quality of forage changes by growth stage and location. There are various factors such as environmental conditions (light, temperature, soil properties, precipitation, altitude, wind), vegetative stage, time of grazing, plant species diversity, and management practices that affect the quantity and quality of forage (Bagheri Rad et al., 2015; Moore et al., 2020).

Forage quality refers to the ability of forage to provide necessary nutrients according to the needs of livestock. The key parameters that determine forage quality are crude protein (CP), dry matter digestibility (DMD), water-soluble carbohydrates (WSC), crude fiber (CF), acid detergent fiber (ADF), neutral detergent fiber (NDF), total ash and metabolizable energy (ME) (Tucak et al., 2021). There is a direct relationship between livestock production and the forage quality (Amiri, 2012; Moore et al., 2020). Maintaining a balance between available nutrients and the nutrient requirements of livestock can help a rangeland manager enhance animal performance to the highest level according to the available forage (Asaadi and Khoshnood Yazdi, 2011; Melo et al., 2022).

The chemical compounds can affect the forage palatability. Several studies have shown that chemical compounds in palatable plants (high CP) and non-palatable plants (with high structural carbohydrates) cause livestock to prefer the former one (Mikhailova et al., 2000). Among several quality traits, CP, ADF, DMD and ME are the most important parameters that determine forage quality (Pinkerton, 2005). In reality, forage quality changes depending on the dominant species and the phenological stages of plants (Schut et al., 2010; Ziehr et al., 2014).

Legume species play a key role in forage production with high quality in rangelands. In addition to their high nutrition values according to CP and other nutrients, these plants are capable of fixing atmospheric nitrogen (bacteria symbiosis) and enhancement of soil fertility (Stødkilde et al., 2019). *Astragalus* is a large and famous genus of the legume family in Iran with 844 species. (Masoumi, 2006). It has been estimated to have about 3000 species as annual or perennial forb, shrub, or bush tree. (Abd El-Ghani et al., 2021; Aliabadi et al., 2023). This genus is nearly composed of 10% of the total plants in Iran (Masoumi, 2006). Javanmard et al. (2020) found that intercropping of forage crops with legumes [grasspea (*Lathyrus sativus* L.), berseem clover (*Trifolium alexandrinum* L.), bitter vetch (*Vicia ervilia* L.), and hairy vetch (*Vicia villosa* L.)] can enhance forage quantity and quality. Zarekia et al. (2021) in the cultivation of *A. vegetus* under rainfed conditions obtained 2000 kg/h forage DM yield. Hajhashemi et al. (2021) reported that *A. cyclophyllon* can provide livestock feeds with high forage quality, nitrogen fixation, facilitating water infiltration, carbon sequestration, etc. However, it is in danger of extinction: due to several factors such as climate change and grazing inten-

sity (Hajhashemi et al., 2021). Several researchers showed that *A. effusus* Bunge is a palatable plant rich in nutrients and with a high tolerance to grazing (Zamani et al., 2010; Yousefzadeh et al., 2010; Ahmadi et al., 2013).

Herbage legumes due to their high CP, good palatability and forage yield are desirable species for feeding livestock (Masoumi, 2006). Zhan-bin and Qing-yi (2013) found that the establishment of *Astragalus adsurgens* in the loss and gully lands in China can improve soil nutrients and organic matter. Nitrogen produced by legumes can be available over a longer period, and has a stimulating effect on forage yields and an important role in organic farming.

There are a few studies about herbaceous *Astragalus* in Iran. The novelty of this research lies in its comprehensive assessment of herbage yield and quality across five native species of milkvetch (*Astragalus* spp.) under rain-fed conditions in Iran. While milkvetch species are well-known for their ecological importance, our study explores their specific attributes in terms of both quantity and quality in the context of livestock forage production Hypothesis: This study was performed to cultivate five *Astragalus* valuable species (including *A. brachyodontus*, *A. effusus*, *A. brevidens*, *A. cyclophyllon*, *A. vegetus*) in the field condition and evaluate their forage quality and quantity. So, the main objective of this research was to determine the forage yield and nutritive value of these species and compare their differences among various phenological stages.

Materials and methods

Study area: The present research was performed in a research station in Homand Absard Rangeland 70 km east of Tehran, on the southern slopes of Alborz Mountains and with an average altitude of 1960 m above sea level and geographic locations (52° 05' 03"E and 35° 38' 55"N) (Table 1). The average annual rainfall and temperature are 338.7 mm and 12 °C, respectively. Homand Absard climate is cold semi-steppe. The soil texture is clay loam and its pH is 7.7. The soil in this station is a part of brown soils with low organic matter and large amounts of lime in lower layers (80 – 100 cm).

Methods: The studied plant species were five perennial *Astragalus* species (*A. brevidens*, *A. vegetus*, *A. cyclophyllon*, *A. effusus*, *A. brachyodontus*) (figure 1). Their seeds were collected from different rangelands of Iran provinces (figure 2). The origins and climatic conditions have been shown in Table 1.

Since *Astragalus* seeds have physical dormancy, the seeds were sacrificed using emery paper to get better field establishment (Zarekia et al., 2013); then, the treated seeds were sown in the field using a complete randomized block with three replications in the autumn, 2017. Each block comprised 5 plots and each plot had two lines in 6 m length. The space between lines was 50 cm and between blocks was 1 m. This experiment was conducted under a dry land farming system. The weeds were taken manually in growth season and no chemical pesticide was used. No data were collected in the establishment year. In the second year, the evaluated parameters were forage production, canopy cover, height, seed yield, and the number of flowering stems.

Table 1. Geographic locations and climatic conditions of the collected seed samples.

| Apecies | Province | Region | Latitude N | Longitude E | Temperature (°C) | Rainfall (mm) | Altitude (masl) |
|-------------------------|-----------------|-------------|------------|-------------|------------------|---------------|-----------------|
| <i>A. brachyodontus</i> | Ghazvin | Zereshk | 36° 25' | 50° 05' | 10 | 400 | 2000 |
| <i>A. effusus</i> | West-Azərbayjan | Dareshogada | 37° 17' | 45° 08' | 10 | 360 | 2000 |
| <i>A. brevidens</i> | Khorasan | Torogh | 36° 15' | 59° 54' | 13 | 277 | 1388 |
| <i>A. cyclophyllon</i> | Chaharmahal | Zevedegan | 31° 58' | 51° 39' | 13 | 622 | 2230 |
| <i>A. vegetus</i> | Kordestan | Saral | 35° 04' | 47° 06' | 11 | 340 | 2100 |

To evaluate the quality of forage in the third year of cultivation (2020), a random sampling was conducted on three-year-old plants in three different stages of growth: vegetative, flowering, and seeding. Three samples were taken for each growth stage. Samples including leaves and stems in the vegetative stage, leaves, stems, and flowers in the flowering stage, and leaves, stems, and seeds in the seeding stage were collected. For each sample, 400 g were taken and placed in an oven at 70 °C for 48 hours. The samples were ground in two stages (industrial mill and laboratory mill). Afterward, NIR (Near Infrared Spectroscopy) model INFRAMATIC8620 instrument was used to estimate nu-

tritional value parameters such as crude protein (CP), dry matter digestibility (DMD), water-soluble carbohydrates (WSC), crude fiber (CF), acid detergent fiber (ADF), neutral detergent fiber (NDF), total Ash, and metabolizable energy (ME). Jafari et al. (2003) provided detailed information regarding laboratory measurements of quality traits and calibrations of NIR.

The collected data were statistically analyzed using a split-plot design based on the completely randomized design in three replications for different growth stages: vegetative, flowering, and seeding. The data were analyzed using SAS9 software, and the means were compared by the DMRT 5%



Figure 1. Picture of five herbaceous milkvetch species (a: *A. effusus*, b: *A. cyclophyllon*, c: *A. brachyodontus* d: *A. vegetus*, e: *A. brevidens*, f: A view of the *Astragalus* farm).

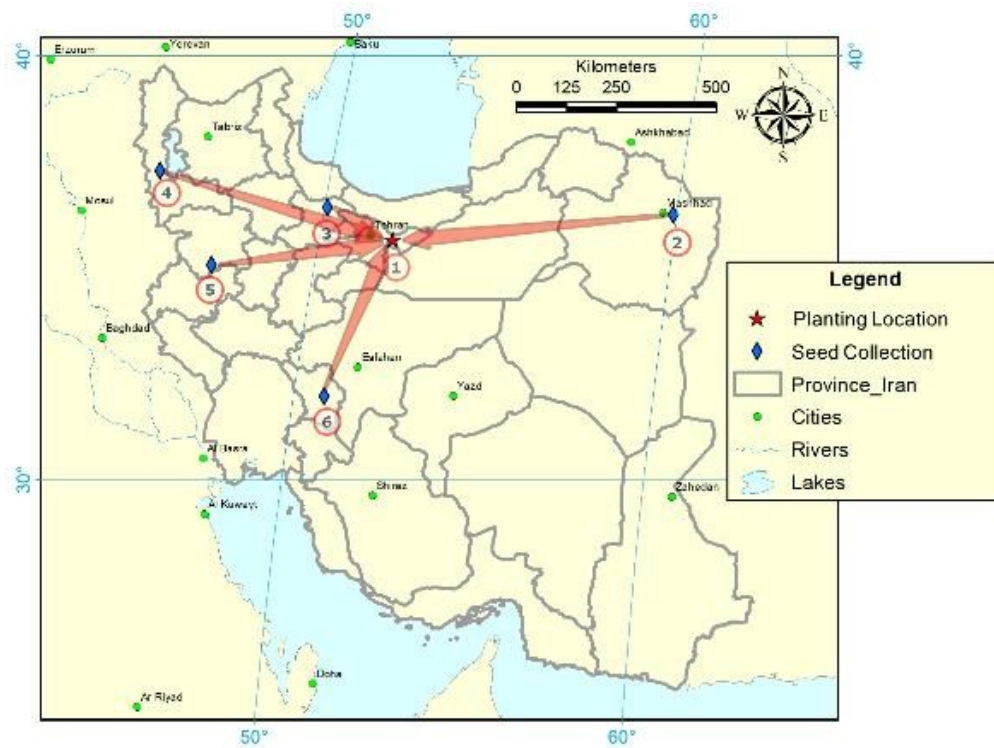


Figure 2. The location of the planting site (1: Homand Absard) and seed collection (2: Khorasan, Torogh; 3: Ghazvin, Zereshk; 4: West-Azərbayjan, Dareshogada; 5: Kordestan, Saral; 6: Chaharmahal, Zeverdegan), Iran.

method.

Results

Yield and morphological parameters

According to Table 2, there were significant differences among species for all measured parameters except forage DM yield ($p < 0.01$). So, means comparisons were made using Duncan test (Table 3).

The results indicated that *A. effusus* with an average value of 2233 kg/ha had the highest forage production (under field conditions and without irrigation). There was no significant difference among *A. effusus*, *A. brevidens*, and *A. vegetus* for canopy cover, but *A. vegetus* with an average value of 7050 cm² had the highest canopy cover area. Similarly, *A. brevidens* with an average value of 70 cm had the highest plant height. Both *A. cyclophyllon* and *A. brachyodontus* had lower mean values of other parameters (Table 3). Although *A. cyclophyllon* had the lowest number of flowering stems, it produced moderate values of seed production. *A.*

effusus with an average value of 38.33 stems per plant had the highest stem numbers. Our finding indicates there was no relationship between seed production and the number of flowering stems.

Quality traits

The results of the analysis of variance for forage quality in five *Astragalus* species in different phenological stages showed that there was no significant difference among species for all the forage quality indices, except CF, WSC and NDF. However, there were significant differences among phenological stages for all quality traits except CP. The species by phenological stage interaction effect was also significant for all traits except CP and ME (Table 4). There was no significant difference among *Astragalus* species for CP (Table 5) while a significant difference was observed among phenological stages (Table 6) so that the highest and lowest amounts of CP were obtained in vegetative and seeding stages, respectively. The highest amount of CP in all species was observed in vegetative stages with

Table 2. Results of analysis of variance (MS) for the effect species, phenological traits and their interaction on DM yield and morphological traits in five *Astragalus* species.

| SOV | DF | MS | | | | |
|---------|----|----------|--------------|--------------|----------------|--------------|
| | | DM yield | Canopy cover | Plant height | Flowering stem | Seeds & Pods |
| species | 4 | 161.6 | 6325357.2** | 109.43* | 500.03** | 18958.93* |
| block | 2 | 51.46 | 1976314.2 | 132.26 | 65.60 | 13677.26 |
| error | 8 | 205.21 | 504064 | 33.43 | 26.93 | 4214.70 |

*, ** = Significant at 5 and 1% probability levels, respectively.

Table 3. The means of DM yield and morphological traits in five *Astragalus* species.

| Species | DM yield (kg/ha) | Canopy cover (cm ²) | Plant height (cm) | Stem number | Seed yield plus pods (kg/ha) |
|-------------------------|------------------|---------------------------------|-------------------|-------------|------------------------------|
| <i>A. brachyodontus</i> | 1993 a | 4938 b | 63.33 ab | 22.33 b | 198 c |
| <i>A. brevidens</i> | 2053 a | 6641 a | 70.00 a | 37.00 a | 411 a |
| <i>A. effusus</i> | 2233 a | 6583 a | 65.3 ab | 38.33 a | 227 bc |
| <i>A. vegetus</i> | 2153 a | 7050 a | 68.33 a | 36.66 a | 349 ab |
| <i>A. cyclophyllon</i> | 1853 a | 3605 b | 55.33 b | 8.66 c | 269 bc |

Means of each column with the same letter is not significantly different according to Duncan test ($P \leq 0.05$).

a range (14.29 to 16.69%). In contrast, the lower values of CP (6.93 to 8.54%) were observed in the seeding stage (figure 3).

For both DMD and ME, There was no significant difference among *Astragalus* species (Table 5). According to our findings, significant decreases were observed in the amounts of both DMD and ME, by increasing the plants' growth age (Table 6). The results showed that the highest values of DMD (67 to 68%) and ME (9.5 to 9.6 MJ/kg) were observed at vegetative and flowering stages in *A. effusus* and *A. cyclophyllon*, respectively (Figs. 2 and 3). For *A. effusus*, both DMD and ME sharply decreased in the seeding stage with values of 43% and 5.5 MJ/kg, respectively (Figs. 4 and 5). For all species, the amount of ME was ranged from (7.97 to 9.64 MJ/kg) at two vegetative and flowering stages (figure 5).

There was no significant difference among *Astragalus* species for WSC (Table 5). According to the results, the highest value of 18.54% was obtained in *A. cyclophyllon* in a vegetative state (figure 6). The lowest amounts of WSC

with values of 11.25 to 16.43% were observed at the seeding stage in all species (figure 6).

For ADF, there was no significant difference among all *Astragalus* species, while significant differences were observed for CF and NDF (Table 4). The species of *A. cyclophyllon* and *A. brachyodontus* with average values of 28.63% and 37.69% had the lowest CF and NDF, respectively (Table 5). Progressing phenology stages caused to increase CF, ADF and NDF parameters in all species (Table 6). For CF, the lowest values (24.55, 25.16 and 26.7) were observed in *A. cyclophyllon*, *A. effusus*, and *A. vegetus*, respectively in the vegetative stage (figure 7). The lowest value of ADF (31.3%) was observed for *A. effusus* in the flowering stage (figure 8). Similarly, the lowest amount of NDF (36.79 to 39.15%) was observed in *A. cyclophyllon* at three phenological stages indicating its higher nutritive value (figure 9).

For total ash, there was no significant difference among *Astragalus* species (Table 5). According to the results, *A. brevidens* had the highest amounts of total ash at the vegeta-

Table 4. Results of analysis of variance (MS) for the effect species, phenological traits and their interaction quality traits.

| S.O.V | DF | MS | | | | | | | |
|------------------------|----|---------|--------|---------|--------|----------|----------|----------|-----------|
| | | CP | DMD | ME | WSC | CF | ADF | NDF | Total ash |
| Block | 2 | 0.12 | 61.35* | 1.77 | 0.33 | 17.02 | 81.77* | 10.68 | 0.27 |
| Species (S) | 4 | 2.33 | 29.43 | 31.29** | 12.36* | 77.01* | 31.92 | 209.69** | 0.96 |
| Phenological stage (P) | 2 | 241.5** | 1083** | 0.85 | 22.2** | 578.45** | 317.12** | 591.93** | 21.12** |
| S × P | 8 | 1.56 | 44.56* | 1.28 | 7.03** | 21.08** | 46.78* | 46.31** | 1.10** |
| Error | 28 | 2.01 | 38.43 | 1.11 | 4.08 | 14.36 | 35.51 | 21.99 | 0.55 |

*, ** = Significant at 5 and 1% probability levels, respectively.

Table 5. Means comparison of forage quality indices in five *Astragalus* species.

| Species | CP (%) | DMD (%) | ME (Mj/kg) | WSC (%) | CF (%) | ADF (%) | NDF (%) | ash (%) |
|-------------------------|---------|---------|------------|---------|---------|---------|---------|---------|
| <i>A. brevidens</i> | 11.76 a | 60.89 a | 8.35 a | 15.3 6b | 34.77 a | 38.40 a | 47.74 a | 7.84 a |
| <i>A. vegetus</i> | 11.66 a | 58.88 a | 8.01 a | 14.52 b | 33.01 a | 39.94 a | 47.17 a | 7.99 a |
| <i>A. effusus</i> | 12.35 a | 59.77 a | 8.16 a | 14.92 b | 32.55 a | 39.26 a | 41.83 b | 7.53 a |
| <i>A. brachyodontus</i> | 12.46 a | 57.96 a | 7.86 a | 14.70 b | 36.45 a | 41.16 a | 49.23 a | 7.25 a |
| <i>A. cyclophyllon</i> | 11.23 a | 62.61 a | 8.64 a | 17.40 a | 28.63 b | 36.14 a | 37.69 b | 8.02 a |

The means of each column with the same letter are not significantly different according to Duncan test ($P \leq 0.05$).

Table 6. Means comparison of forage quality indices in different phenology stages.

| Phenological stages | CP (%) | DMD (%) | ME (Mj/kg) | WSC (%) | CF (%) | ADF (%) | NDF (%) | ash (%) |
|---------------------|---------|---------|------------|---------|---------|---------|---------|---------|
| Vegetative | 15.76 a | 66.11 a | 9.24 a | 16.51 a | 27.27 c | 35.85 b | 37.85 c | 8.75 a |
| Flowering | 12.16 b | 63.64 a | 8.81 a | 16.05 a | 32.34 b | 36.82 b | 46.16 b | 7.99 b |
| Seeding | 7.75 c | 50.31 b | 6.55 b | 13.56 b | 39.63 a | 44.26 a | 50.17 a | 6.42 c |

The means of each column with the same letter are not significantly different according to Duncan test ($P \leq 0.05$).

tive growth stage (9.56%) (figure 10). The lowest amounts of total ash were observed at the seeding stage in all species.

Discussion

Some studies have shown that certain species of *Astragalus*, a plant found in semi-steppe rangelands in Iran, are capable of producing high-quality forage (Ehsani et al., 2021; Zarekia and Mirhaji, 2017). Our research has come to the same conclusion. Specifically, we found that three-year-old *Astragalus* plants produced around 2000 kg/h of forage under natural rainfall conditions (In farm conditions). The best time for harvesting this forage was during the flowering stage in June. The DM yield was comparable to that of *Onobrychis sp.* ecotypes, with value of 800 kg/ha in a different research farms in Homand, Damavand, Iran (Ansari and Zohdi, 2004). Other studies have also shown that leguminous plants such as *Medicago sp.* and *Onobrychis sp.* are important for forage production for livestock in dry land farming in Iran. These plants are cultivated for a long time and they produce about 2 tons/ha (Cicek et al., 2020; Mohajer et al., 2011). However, breeding programs should focus on increasing more DM yield (Jafari et al., 2014).

One of the problems with restoring destroyed and inefficient rangelands is the lack of high-quality seeds. Our research showed that seed production of *Astragalus* is possible under suitable climatic conditions, with an estimated amount of up to 411 kg/ha. *A. brevidens* had the highest seed and pod

production. This yield was comparable to that of *Medicago sativa* and *Onobrychis sativa* in dry farming systems (Jafari et al., 2009).

In our study, *A. cyclophyllon* and *A. brachyodontus* had the lowest mean values for many parameters. On the other hand, *A. vegetus*, *A. brevidens*, and *A. effusus* were found to be successful for rangeland improvement in similar climatic conditions (rainfall of 300 mm and average temperature of 11 °C) in Homand station. *A. effusus* is a palatable forage and has high nutritive value, and is tolerant of grazing and soil conservation (Yousefzadeh et al., 2010). However, it should not be subjected to high grazing pressure as this may reduce its production (Ghasriani et al., 2016).

To effectively manage rangelands, it is important to balance the nutritional requirements of grazing animals with the fluctuation of forage quantity and quality throughout the year. Arzani et al. (2014) suggest that understanding the critical boundaries of forage quality indices is necessary for this balance. Studies have shown that legumes such as sainfoin (*Onobrychis viciifolia*) have high forage quality, with CP values over than 16% coupled with high ME levels (Legendre et al., 2018; Gayrard et al., 2021). However, as plants grow, the amounts of important forage quality parameters such as CP, DMD, and ME tend to decrease, as found by Ranjbarfordoei et al. (2020). For example, CP in *Astragalus* species was estimated at up to 15% during the vegetative stage (Tahmasebi et al., 2020). Other studies by Kaithwas et al. (2020) found high amounts of CP and di-

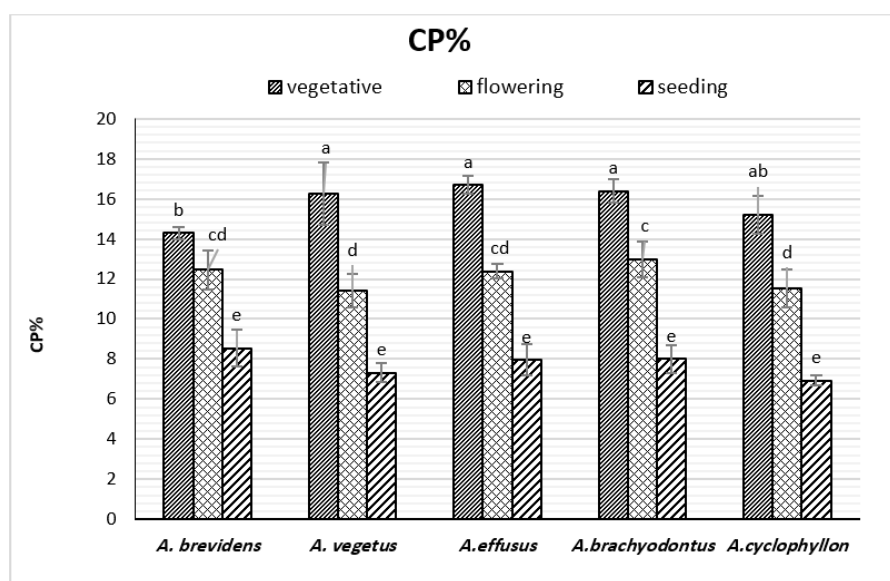


Figure 3. The Mean \pm SE (Standard error) of crude protein (CP %) in three phenological stages in five milkvetch species.

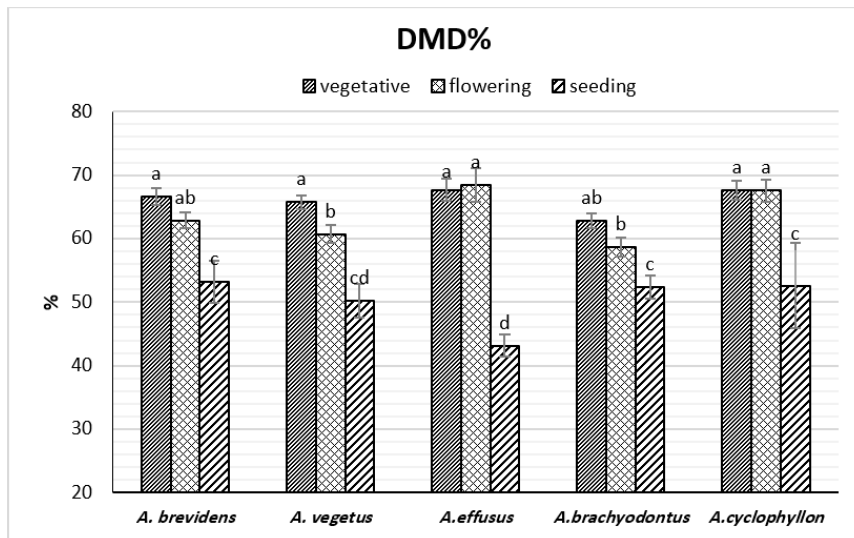


Figure 4. The Mean ± SE (Standard error) of dry matter digestibility (DMD %) in three phenological stages in five milkvetch species.

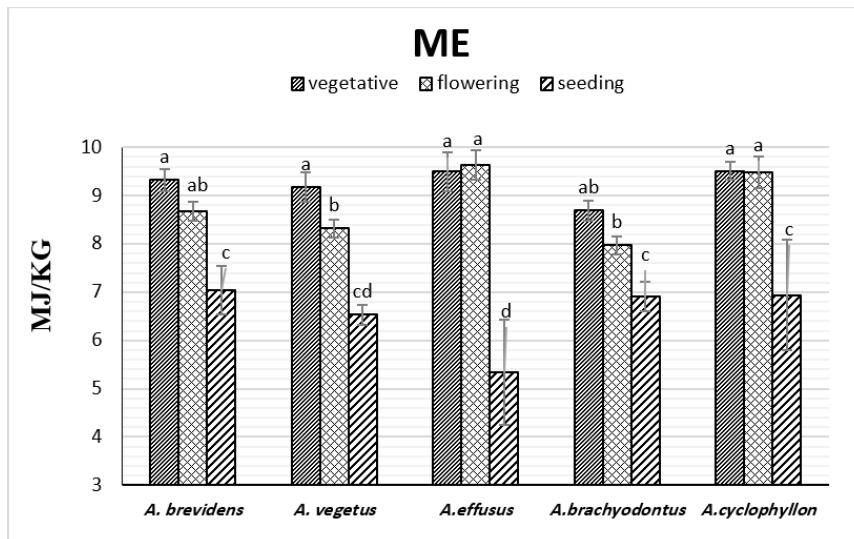


Figure 5. The Mean ± SE (Standard error) of Metabolizable Energy (ME) in three phenological stages in five milkvetch species.

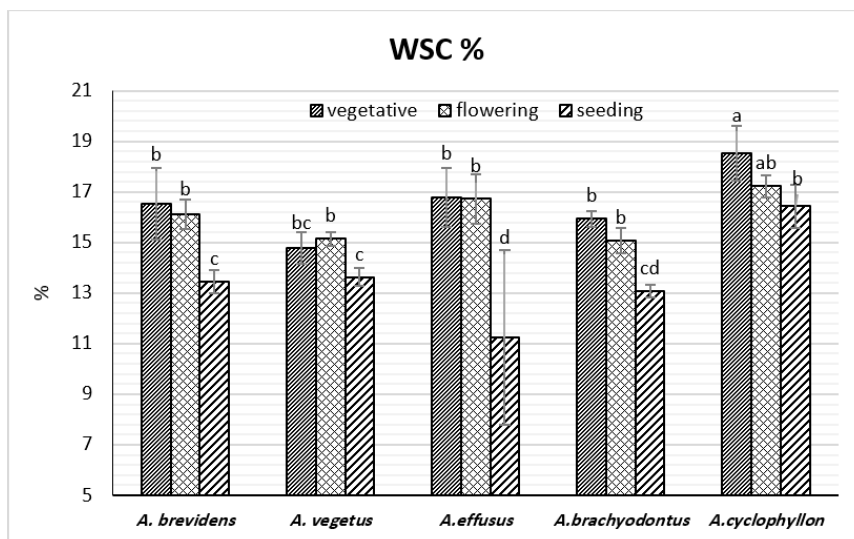


Figure 6. The Mean ± SE (Standard error) of water-soluble carbohydrates (WSC %) in three phenological stages in five milkvetch species.

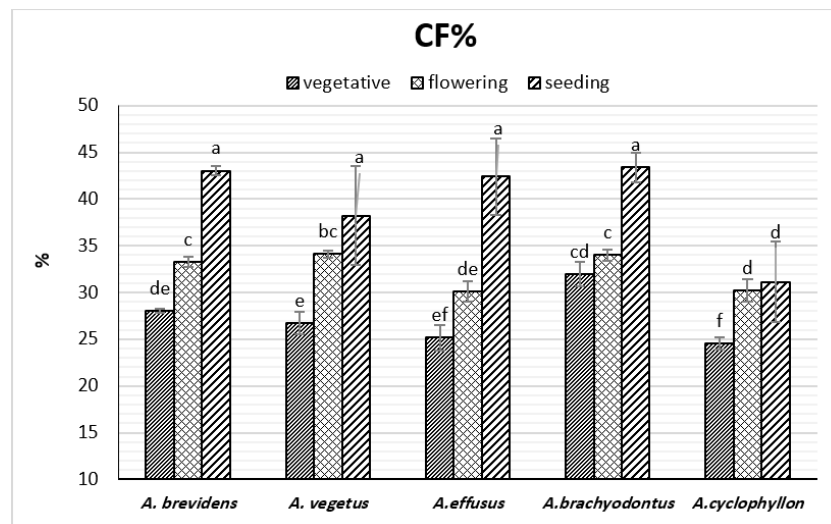


Figure 7. The Mean \pm SE (Standard error) of crude fiber (CF %) in three phenological stages in five milkvetch species.

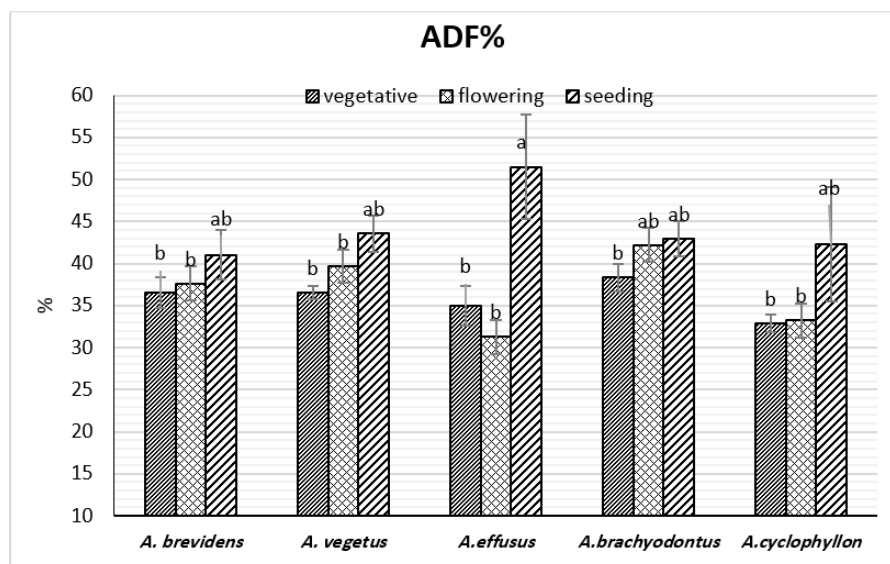


Figure 8. The Mean \pm SE (Standard error) of Acid detergent fiber (ADF %) in three phenological stages in five milkvetch species.

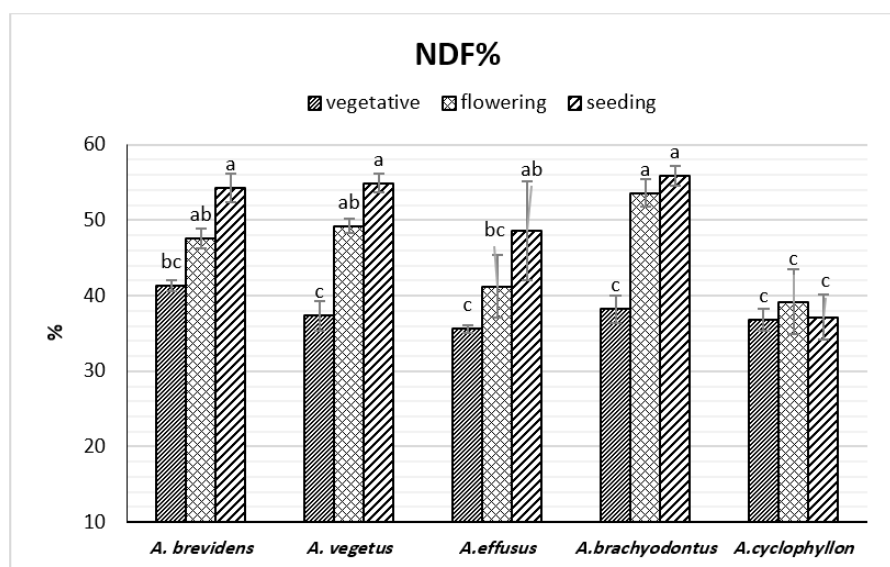


Figure 9. The Mean \pm SE (Standard error) of neutral detergent fiber (NDF %) in three phenological stages in five milkvetch species.

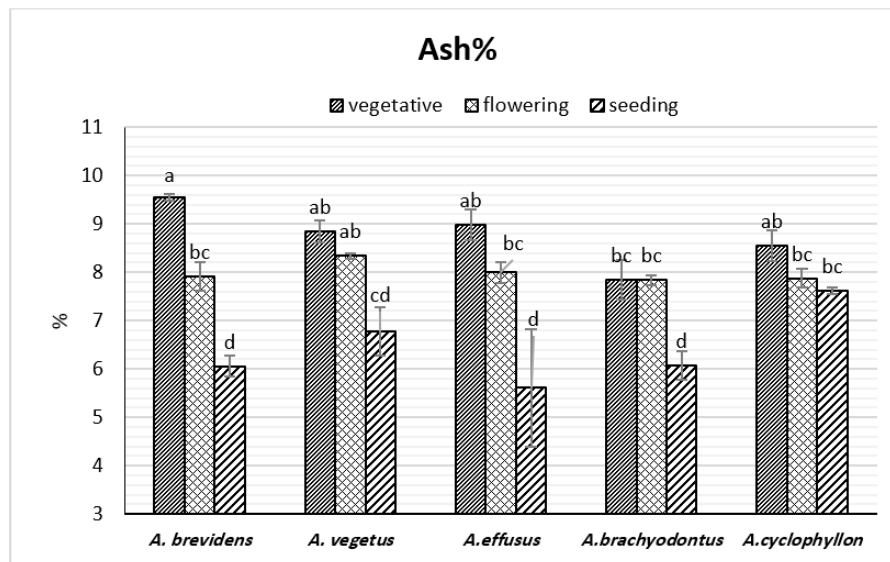


Figure 10. The Mean \pm SE (Standard error) of dry matter digestibility (DMD %) in three phenological stages in five milkvetch species.

gestible protein in five types of legumes (Berseem, lucerne, desmenthus, lablab, and tylosanthes), which are excellent resources for livestock feeding.

In our study, we found that undesirable quality factors such as CF, ADF, and NDF were the lowest in the vegetative stage and the highest in the seeding stage. Previous research by Arzani et al. (2001) also showed that protective and firm tissues in plants increase as they grow, which are made up of structural carbohydrates like cellulose, hemicellulose, and lignin. This results in an increase in plant fiber percentage as the plant grows and develops (McDonald et al., 1996; Shahri et al., 2019). As plants mature, the DMD decreases, which is in agreement with the findings of Akbarinia and Koocheki (1992), who attributed this to the increase in structural tissues in stems.

Based on the results of the study, the vegetative stage was found to have the best forage quality in the *Astragalus* species. Livestock grazing during this stage would result in the best livestock performance, but the forage yield is low in vegetative stage. However, if grazing is delayed until the flowering stage, forage production potential is high and forage quality is good with desirable levels of CP, ME, and DMD. It is important to follow permissible operating limits to maintain and breed these valuable species, especially in rangelands with poor conditions.

The Ash content among the different *Astragalus* species studied showed no significant difference, but the amount of ash decreased as the plant grew. In a study conducted by Dashti et al. (2016), a positive correlation was found between protein and ash in *Elymus hispidus*. Enhanced levels of these parameters also resulted in increased digestibility. The increase or decrease in ash with plant growth could be attributed to various soil and habitat conditions (Farrukh and Mufakhirah, 2009). Overall, forage quality parameters differed among species in each environment and growing season. Similar to this, other researchers have also reported differences in forage factors such as CP, ADF, NDF, and DMD in legumes, both within and between species.

Conclusion

The *Astragalus* species that were studied are highly valuable and desirable plants in rangelands in Iran. To maintain and revive these species, it is important to implement grazing management programs. Due to their ability to fix soil nitrogen and provide high-quality forage, these species can be utilized in projects aimed at converting abandoned dry land farming into forage production areas using dry farming systems. Additionally, they can be used for the restoration of degraded rangelands in their habitats. The cultivation of these legumes is a priority in all restoration and improvement projects in degraded rangelands, given their important role in increasing soil fertility and improving the quality and quantity of forage in plant compositions in rangelands. Among the studied species, *Astragalus effusus* and *Astragalus cyclophyllon* were excellent and superior species for both yield and quality traits.

Authors Contributions

All authors have contributed equally to prepare the paper.

Availability of Data and Materials

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Conflict of Interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

- Abd El-Ghani M. M., El-Sayed A. S. A., Moubarak A., Rashad R., Nosier H., Khattab A. (2021) Biosystematic study on some Egyptian species of *Astragalus* L. (Fabaceae). *Agriculture* 11 (2): 125. DOI: <https://doi.org/10.3390/agriculture11020125>.
- Ahmadi A., Shahmoradi A., Zarekia S., Ahmadi E., Nateghi S. (2013) Autecological study of *Astragalus effusus* in rangelands of west Azerbaijan province, Iran. *Iranian Journal of Range and Desert Research* 20 (1): 172–181.
- Akbarinia A., Koocheki A. (1992) Investigation of effects of different harvesting stages on growth, productivity and quality of some barley varieties. *Journal of Pejouhesh and Sazandegi* 15:40–43.
- Aliabadi F., Bagheri A., Abbasi S., Saeidi H., Blattner F. R. (2023) High genetic diversity in an endemic and vulnerable species: Evidence from *Astragalus cyclophyllon* (Fabaceae) in Iran. *Genetic Resources and Crop Evolution*, 1–10. DOI: <https://doi.org/10.1007/s10722-023-01550-7>.
- Amiri F. (2012) Comparison of nutritive values of grasses and legume species using forage quality index. *Songklanakarinn Journal of Science & Technology* 34 (5): 577–586.
- Ansari N., Zohdi M. (2004) Investigating the need for fertilizer and *Onobrychis sativa* seeds in the rainy conditions of Lorestan province. *Iranian Journal of Range and Desert Research* 11 (3): 309–322.
- Arzani H., Motamedi J., Hosseini S. R. (2014) Forage quality of important range species in summer rangelands of Saraliabad. *Iranian Journal of Range and Desert Research* 21 (4): 651–662.
- Arzani H., Torkan J., Jafari M., Nikkhab A. (2001) Investigation of effects of phenological stages and environmental factors (soil and climate) on forage quality of some important range species. *Journal of Agricultural Sciences* 32:385–397.
- Asaadi A. M., Khoshnood Yazdi A. K. (2011) Phenological stage effects on forage quality of four forbs species. *Journal of Food, Agriculture & Environment* 9 (2): 380–384.
- Bagheri Rad E., Mesdaghi M., Ahmad N., Abdullah M. (2015) Nutritional quality and quantity of available forages relative to demand: A case study of the goitered gazelles of the Golestan National Park, Iran. *Rangelands* 37 (2): 68–80. DOI: <https://doi.org/10.1016/j.rala.2015.01.004>.
- Cicek H., Ates S., Ozcan G., Tezel M., Kling J. G., Louhaichi M., Keles G. (2020) Effect of nurse crops and seeding rate on the persistence, productivity and nutritive value of sainfoin in a cereal-based production system. *Grass and Forage Science* 75 (1): 86–95. DOI: <https://doi.org/10.1111/gfs.124675>.
- Dashti M., Jafari A. A., Zarif Ketabi H., Saghafi Khadem F. (2016) Investigation of yield and quality traits of three varieties of *Elymus hispidus* in different phenological stages under dryland farming. *Iranian Journal of Range and Desert Research* 22 (4): 683–694.
- Ehsani S. M., Niknahad Gharmakher H., Motamedi J., Akbarlou M., Sheidai Karkaj E. (2021) Effect of wheat Straw biochar and lignite on the nutritional value of *Nitraria schoberi* and *Astragalus podolobus* in greenhouse condition. *Journal of Rangeland Science* 11 (1): 44–53.
- Farrukh H., Mufakhirah J. (2009) Nutritional evaluation of some forage plants from Harbio Rangeland, Kalat, Pakistan. *Pakistan Journal of Botany* 41 (3): 1137–1154.
- Gayraud C., Gombault P., Bretaudeau A., Hoste H., Gidenne T. (2021) Nutritive value of dehydrated sainfoin (*Onobrychis viciifoliae*) for growing rabbits, according to the harvesting stage. *Animal Feed Science and Technology* 279:114995.
- Ghasriani F., Mohebbi A., Shirmardi H. A., Mirakhorli R., Eftekhari A. (2016) Determining the allowable use for *Astragalus effusus* Bunge in the mountainous and semi-steppe rangelands of Iran. *Journal of Biodiversity and Environmental Sciences* 9 (4): 34–39.
- Hajhashemi R., Ghehsareh Ardestani E., Ebrahimi A., Nikookhah F. (2021) Influence of seed inoculation with promoting rhizobacteria on the germination and growth traits of *Astragalus cyclophyllon* Beck under drought stress. *Environmental Resources Research* 9 (2): 199–212. DOI: <https://doi.org/10.22069/IJERR.2021.19439.1348>.
- Jafari A., Connolly V., Frolich A., Walsh E. J. (2003) A note on estimation of quality parameters in perennial ryegrass by near-infrared reflectance spectroscopy. *Irish Journal of agricultural and food research*, 293–299.
- Jafari A., Maddah Arefi H., Ghamari zare A. (2009) Comprehensive project of genetic studies and breeding rangeland species (grass and legumes). *Research Institute of Forests and Rangelands, Tehran*
- Jafari A. A., Rasoli M., Tabaei-Aghdaei S. R., Salehi P. (2014) Evaluation of herbage yield, agronomic traits and powdery mildew disease in 35 populations of sainfoin (*Onobrychis sativa*) across 5 environments of Iran. *Romanian Agricultural Research* 31:41–48.
- Javanmard A., Machiani M. A., Lithourgidis A., Morshedloo M. R., Ostadi A. (2020) Intercropping of maize with legumes: A cleaner strategy for improving the quantity and quality of forage. *Cleaner Engineering and Technology* 1:100003. DOI: <https://doi.org/10.1016/j.clet.2020.100003>.
- Kaithwas M., Singh S., Prusty S., Mondal G., Kundu S. S. (2020) Evaluation of legume and cereal fodders for carbohydrate and protein fractions, nutrient digestibility, energy and forage quality. *Range Management and Agroforestry* 41 (1): 126–132.
- Legendre H., Saratsi K., Voutzourakis N., Saratsis A., Stefanakis A., Gombault P., Sotiraki S. (2018) Coccidiostatic effects of tannin-rich diets in rabbit production. *Parasitology Research* 117 (12): 3705–3713. DOI: <https://doi.org/10.1007/s00436-018-6069-2>.
- Masoumi A. A. (2006) *Astragalus* in Iran. *Research Institute of Forests and Rangelands, Tehran*, 786.
- McDonald P., Edwards R. A., Greenhalgh J. F. D., Morgan C. A. (1996) Animal nutrition. *Longman, London* 5th:607.
- Melo C. D., Maduro Dias C. S., Wallon S., Borba A. E., Madruga J., Borges P. A., Elias R. B. (2022) Influence of climate variability and soil fertility on the forage quality and productivity in Azorean pastures. *Agriculture* 12 (3): 358. DOI: <https://doi.org/10.3390/agriculture12030358>.
- Mikhailova E. A., Bryant R. B., Cherney D. J. R., Post C. J., Vassenev I. I. (2000) Botanical composition, soil and forage quality under different management regimes in Russian grasslands. *Agriculture, ecosystems & environment* 80 (3): 213–226. DOI: [https://doi.org/10.1016/S0167-8809\(00\)00148-1](https://doi.org/10.1016/S0167-8809(00)00148-1).
- Mohajer S., Jafari A. A., Taha R. M. (2011) Studies on seed and forage yield in 10 populations of sainfoin (*Onobrychis saliva*) grown as spaced plants and swards. *Journal of Food Agriculture & Environment* 9 (1): 222–227.
- Moore K. J., Lenssen A. W., Fales S. L. (2020) Factors affecting forage quality. *Forages: The science of grassland agriculture* 2:701–717. DOI: <https://doi.org/10.1002/9781119436669.ch39>.
- Pinkerton B. (2005) Forage quality. *Clemson University Cooperative Extension Service, South Carolina, USA*, 998.
- Ranjbarfordoei A., Van Damme P., Samson R., Zamani G. (2020) Phenological analysis of forage quality in *Astragalus effusus* (Bunge). *Indian Journal of Crop Science* 4:137–140.
- Schut A. G. T., Gherardi S. G., Wood D. A. (2010) Empirical models to quantify the nutritive characteristics of annual pastures in south-west Western Australia. *Crop and Pasture Science* 61 (1): 32–43. DOI: <https://doi.org/10.1071/CP084383>.
- Shahri M., Ariapour A., Mehrabi H. R. (2019) Forage quality of tree species rangeland (*Astragalus gossypinus*, *Trifolium repens* and *Poa bulbosa*) in different phenological stages in Sarab-Sefid Borujerd rangeland, Lorestan province. *Iranian Journal of Range & Desert Research* 26 (4): 986–1002.

- Stødkilde L., Damborg V. K., Jørgensen H., Lærke H. N., Jensen S. K. (2019) Digestibility of fractionated green biomass as protein source for monogastric animals. *Animal* 13 (9): 1817–1825. DOI: <https://doi.org/10.1017/S1751731119000156>.
- Tahmasebi P., Manafian N., Ebrahimi A., Omidipour R., Faal M. (2020) Managing grazing intensity linked to forage quantity and quality trade-off in semiarid rangelands. *Rangeland Ecology & Management* 73 (1): 53–60. DOI: <https://doi.org/10.1016/j.rama.2019.08.011>.
- Tucak M., Ravlić M., Horvat D., Čupić T. (2021) Improvement of forage nutritive quality of alfalfa and red clover through plant breeding. *Agronomy* 11 (11): 2176. DOI: <https://doi.org/10.3390/agronomy11112176>.
- Yousefzadeh K., Houshmand S., Zamani G. (2010) Karyotype analysis of *Astragalus effusus* Bunge (Fabaceae). *Caryologia* 63 (3): 257–261. DOI: <https://doi.org/10.1080/00087114.2010.10589735>.
- Zamani G., Ranjbar A., Saeedfar M. (2010) Comparative study of *Astragalus effusus* Bunge forage quality in three growth stages and management systems. *Iranian Journal of Forest and Range Protection Research* 8 (1): 1–9.
- Zarekia S., Jafari A. A., Khodaghali M., Zare N. (2021) Perennial herbaceous *Astragalus*, a source of forage production in rangelands of Iran. *Iran Nature* 6 (1): 71–79.
- Zarekia S., Jafari A. A., Zandi Esfahan E., Fallah Hosseini L. (2013) Study on germination of some perennial herbaceous *Astragalus*. *Iranian Journal of Range and Desert Research* 20 (1): 88–100.
- Zarekia S., Mirhaji T. (2017) Preliminary evaluation of some perennial herbaceous *Astragalus* to select superior genotypes Homand-Abesard Rangeland Research Station. *Journal of Plant Ecosystem Conservation* 5 (10): 88–99.
- Zhan-bin W., Qing-yi W. (2013) Cultivating Erect Milkvetch (*Astragalus adsurgens* Pall.) (Leguminosae) improved soil properties in Loess Hilly and Gullies in China. *Journal of Integrative Agriculture* 12 (9): 1652–1658.
- Ziehr R. D., Rea G. L., Douglas J. L., Spaeth K. E., Peacock G. L., Muir J. P. (2014) Ontogenesis and nutritive value of warm-season perennial bunch grasses. *Tropical Grasslands-Forrajes Tropicales* 2 (2): 188–196. DOI: [https://doi.org/10.17138/TGFT\(2\)188-196](https://doi.org/10.17138/TGFT(2)188-196).