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Research and Full Length Article:

Effects of Sowing Season and Cultivation Method on Vegetative Traits and Establishment of *Astragalus lilacinus* in Ardebil Province, Iran

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Abstract. Choosing the suitable species, sowing method and sowing season refers to three important factors for the success of rangeland restoration. The present study was conducted to investigate the effects of sowing season and sowing methods on vegetative growth and establishment of *Astragalus lilacinus* in rangelands of Ardabil province during 2014-2015. Seeds of *Astragalus lilacinus* collected from its natural habitats and after its viability test, seeds sown in a split-plot design based on a randomized complete block with three replications. Factor A was the sowing season at two levels (autumn and spring) and Factor B was the sowing method at two levels (scatter seeding and row seeding). The seeds were sown under dryland farming conditions. Data were collected for establishment rate, canopy cover, plant height, and number of flowering stems over two years. The data were analyzed of variance and the means comparison was performed using Duncan's method. The results showed that higher establishment percent with an average value of 33.6% was obtained in the scatter seeding that was significantly higher than row seeding (23.6%). The sowing season by sowing method interaction effect was significant for canopy cover ($P<0.05$) and higher value of canopy cover (2398cm^2) was obtained in autumn season using the scatter seeding method.

Key words: *Astragalus lilacinus*, Rangeland restoration**,** Natural rainfed**,** Ardabil province

Introduction

Rangeland seeding programs in Iran went back to about 50 years ago, which were conducted in the highland rangeland at Homand research station, Damavand, Iran (Azarnivand and Zare Chahouki, 2008). Available reports indicated that many native range species had good success and could be well established in areas with annual precipitation of more than 360 mm (Ananymous, 1998). According to the literature reviewed, there is no research for cultivation and domestication of *Astragalus lilacinus* in Iran. But, there are some reports for some other *Astragalus* species. Sharifi *et al*. (2010) reported that *Astragalus brachyodantus* grows in the middle elevations (1700-2500 m) in the southern part of the Ardabil province, Iran. This species has strong roots and it is resistance to drought and livestock trampling and it could be survived in natural habitats (Sharifi *et al*., 2010). Mohamadi (2016) in a study on the ecological requirements of *Astragalus brevidens* in Khorasan Razavi province, Iran found that this species has a good distribution in the cool semi-arid climate and highlands of Provence. Azarnivand and Zare Chahouki (2008) in a study on the establishment of *Astragalus squarrosus* in Yazd province, Iran suggested that this species could be established through seeding in the areas with normal precipitation. A study was conducted on the effects of environmental factors on forage production in steppe and semi-steppe rangelands of Esfahan province, Iran, Jaberalansar *et al*. (2016) showed that precipitation in the wettest month, annual precipitation, high altitude, organic matter, and potassium were the most influential factors in the forage production of range species in the semi-steppe region. Brati *et al*. (2015) in a study of yield evaluation of *Medicago sativa L.* and *Bromus tomentellus* in mono-cropping and mix cropping suggested that *Bromus tomentellus* in both autumn and spring sowing dates and *Medicago sativa* in spring date were more successful. Moreover, the mixed cropping of *Medicago sativa* and *Bromus tomentellus* resulted in a higher production compared to pure cropping (Brati *et al*., 2015).

Abtahi (2016) in a study of the effect of seed depth and water storage on the establishment of five rangeland species in the highlands of Kashan, Iran found that sowing depth influenced the survival rate of *Prangos uloptera* so that higher survival rate (73%) was obtained at the depth of 2.5 cm. In the same study, the highest survival (53%) of *Onobrychis melanotricha* was recorded in much lower depth (1 cm).

Jankju *et al*. (2010) in a study on the autecology of *Astragalus arpilobus* in North Khorasan province, Iran showed that the initial plant establishment was successful under pot cultivation conditions; however, the germination percent was low (24%), which increased by 51% by scarification treatment. Generally, the good establishment rate, high nutritional value, and a suitable phenological calendar in harmony with grazing season had introduced it as a promising species for improvement of winter rangelands in the northeast of the country (Jankju *et al*., 2010).

Ahmadi *et al*. (2013) investigated the ecological characteristics of *Astragalus effuses* in the rangelands of West Azarbaijan, Iran. They recommended the cultivation of this species for rangeland improvement and reclamation. The forage yield of *Astragalus effuses* in the first harvest in the second year in autumn sowing was higher than that of second one (Ahmadi *et al*., 2013). Hosseini (2012) in a study of forage production of three *Astragalus* species found average values of 1049, 267, and 286 kg h^{-1} for *A. sumbari, A. lilacinus*, and *A. podolobus*, respectively. Ezzat *et al*. (2018) in the evaluation of the forage quality and nutritional value of some forb and grass species in Sudan showed a higher

concentration of macro minerals in forbs compared to grasses. Azhir and Fayaz (2017) in a study on cultivation method and sowing seasons of *Vicia subvillosa* in Mazandaran, province, Iran found higher seed germination and survival rate in the autumn sowing date than to the spring sowing. Moreover, row seeding was superior to the scattering seeding in the study area.

Azimi *et al*. (2016) in evaluation of the effect of SiO_2 Nano particle on seed germination of *Astragalus squarrosus* showed that the seed scarification followed by Nano-particle treatments can improve the seed germination and consequently, the plant establishment. Finally, Zarekia *et al*. (2016) in evaluation of the effects of sowing season on the vegetation indices of *A. effusus* and *A. brachyodontus* genotypes at the Homand Absard research station, Damavand, Iran found a significant difference between the sowing seasons and higher forage production, plant height, canopy cover, and stem numbers were obtained in autumn cultivation. The present study aimed to determin the best sowing method and sowing season of *Astragalus lilacinus* to obtain the highest yield.

Materials and Methods

Site information

The study area is located in the rangelands of the West Meshkinshar Region, Ardabil province, Iran, lying between 38° 22 ' 06" to 38° 22 ' 15" N and 47°26' 39" to 47° 26' 47" E, at an altitude of 1250 m above sea level. Based on the Emberger method, the climate of the study area is semi-arid to semi-wet cold. The average annual temperature is 9.5°C and the average annual precipitation is 420 mm (Table. 1). According to the Ombrothermic diagram, the number of dry months is about four (Fig. 1).

Table 1. Long-term (1996-2018) climatic information of Meshkinshahr synoptic station, Ardebil province, Iran

Month	Long-term average temperature (°C)	Average maximum temperature ((°C	Average minimum temperature (°C)	Average long-term precipitation (mm)	Average relative humidity (%)	Average absolute maximum Temperature (°C)	Absolute minimum average temperature(°C)
January	0.4	4.1	-3.4	21	56.6	11.9	-11.4
February	1.4	5.4	-2.7	29	58.3	13.3	-10.2
March	5.5	10.0	1.0	40	57.3	18.4	-7.2
April	10.2	14.9	5.5	52	60.9	23.9	-3.1
May	14.7	19.8	9.6	70	62.2	27.2	4.3
June	19.0	24.6	13.4	34	56.2	31.0	8.7
July	21.3	26.6	16.0	21	53.6	32.3	11.8
August	21.5	26.9	16.2	13	53.7	33.5	12.2
September	17.5	22.6	12.4	22	62.9	30.4	6.8
October	12.8	17.3	8.3	29	61.8	26.0	1.2
November	6.4	10.3	2.5	29	60.5	18.1	-4.9
December	2.9	6.7	-1.0	20	55.1	14.6	-8.5

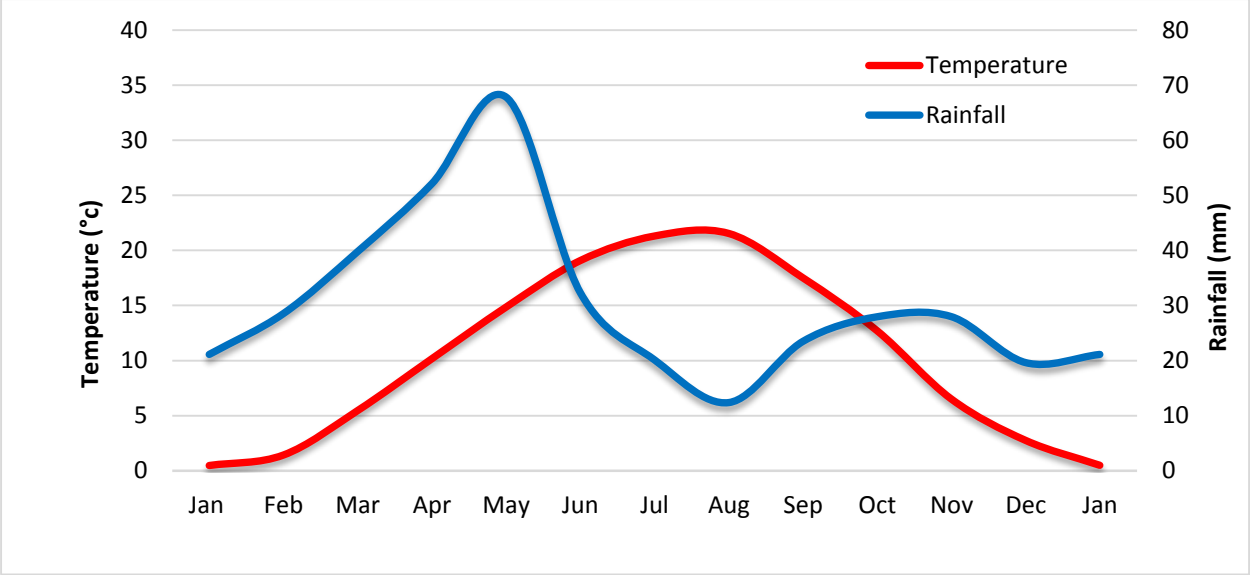

Fig. 1. Ombrothermic diagram of Meshkinshahr region based on a 23-year average (1996-2018)

Research Method

The seeds of *Astragalus lilacinus* were collected from its natural habitats and after germination test, seeds were sown in a split-plot design based on a randomized complete block with three replications. Factor A was the sowing season at two levels (autumn and spring cultivation) and factor B was the sowing method in two levels (Scatter seeding and row seeding). The seeds of *Astragalus lilacinus* were sown in two methods, i.e. seed broadcasting and row seeding in two cultivation dates (autumn and spring). The size of plots was 5 × 8 m and the distance between plots was 1 m. In the row seeding method, the row distance was 50 cm. The sowing depth was about 2.5 to 3 cm. In the scatter seeding method, the seeds assigned to each plot were evenly distributed by hand in the plot area. Based on the experience of cultivation in the region, the amount of seed sown was 8-10 kg h^{-1}. Considering the viability, the seed content of 20-25 kg/ha was considered. This study was conducted in three years from 2013 to 2015. The traits of establishment rate, canopy cover, plant height and stems number were measured. Data analysis was performed using SAS statistical software. In addition, means comparison was performed using Duncan's multiple range tests at the 5% probability level.

Results

According to the results of ANOVA, a significant difference ($P<0.05$) was found between the sowing methods (scatter seeding and row seeding) for the establishment rate of *Astragalus lilacinus*. However, there was no significant difference between the two sowing season for this trait (Table 2). A split plot in time analysis of variance was made for other traits such as canopy cover, plant height and stems number over two years (Table 3). Result showed significant effect of sowing method on canopy cover and stem number and establishment rate ($P<0.05$). The sowing method by sowing season interaction effect was significant for canopy cover. Also, the sowing method by year interaction effect was significant for the canopy cover and stems number (Table 3). The sowing season × sowing method × year interaction effect was not significant for all of the traits and finally, the effect of year was significant for all three traits and higher mean values

canopy cover, plant height and stems number were obtained in the second year, respectively (Tables 3 and 4).

The effect of sowing season was not significant and there was no difference between two seasons for all of traits (Table 5). In comparisons between sowing method, higher values of establishment rate (33.67 vs. 23.67), canopy cover (1842.3 vs. 915.4) and stems number (4.40 vs. 3.67) were obtained in scatter seeding than row seeding, respectively (Table 6).

The means comparison of sowing season by sowing method interaction effects showed that the higher establishment rate with values of 34.67 and 32.67% were obtained for scatter seeding in spring and autumn, respectively. For canopy cover, the higher value of (1980.7 cm^2) was related to the spring scatter seeding followed by autumn scatter seeding with a value of (1703.8 cm^2). However, no significant difference was observed in the two traits for plant height. For stem number, the higher values of 4.63 and 4.17 were obtained for scatter seeding in spring and autumn, respectively (Table 7).

Table 2. Analysis of variance (MS) of establishment percentage of *Astragalus lilacinus*

Source of variance	DF	MS
Block	2	426.66
Sowing Season (S)	1	81.66
Error1	2	181.66
Sowing Method (M)	1	1500 *
S x M	1	1.66
Error2	4	186.66

*, **= Means of squares are significant at 5% probability levels

Table 3. Analysis of variance (MS) split-plot in time for canopy cover, plant height and stem number of *Astragalus lilacinus*

Source	DF	Canopy cover	Plant height	Flowering stem number
Sowing Season (S)	1	57260.6	3.0	2.7
Replication	2	910324	102.56	9.1
Error 1	2	124965.7	71.5	3.47
Sowing Method (M)	1	25774706*	2.4	16.1*
S × M	1	3083200*	9.07	0.83
Error2	4	278579.1	39.1	6.3
Year (Y)	1	124717494 **	316.8 *	346.8 **
S × Y	1	3007183.9	0.0083	0.83
M × Y	1	22100066 **	66.0	48.1*
S × M × Y	1	1174922.4	200.2	1.6
Error3	8	913169.5	221.9	12.8

*, **= Means of squares are significant at 5 and 1% probability levels

Table 4. Mean comparison between two growing years studied traits

Year	Canopy cover (cm^2)	Plant height (cm)	Flowering stem (number)
Year 1	359.4[b]	38.27[b]	2.33[b]
Year 2	2398.3[a]	41.52[a]	5.73[a]

Means with the same letter are not significantly different according to Duncan's test P<0.05).

Table 5. Mean comparison between two sowing seasons for the studied traits

Seasons	Establishment %	Canopy cover (cm^2)	Plant height (cm)	Flowering stem (number)
Spring	29.85 [a]	1357.0 [a]	40.0 [a]	4.18 [a]
Autumn	27.50 [b]	1400.7 [a]	39.7 [a]	3.88 [a]

Means with the same letter are not significantly different according to Duncan's test P<0.05).

Table 6. Mean comparison between two sowing methods for the studied traits

Sowing Methods	Establishment %	Canopy Cover (cm^2)	Plant height (cm)	Flowering stem number
Scatter seeding	33.67[a]	1842.3[a]	40.00[a]	4.40[a]
Row seeding	23.67[b]	915.4[b]	39.75[a]	3.67[b]

Means with the same letter are not significantly different according to Duncan's test (P<0.05).

Table 7. Mean comparison between Sowing Season by Sowing Method interaction effects of the studied traits

Sowing season	Sowing Method	Establishment %	Canopy Cover (cm^2)	Plant height (cm)	Flowering Stem (Number)
Spring	Scatter seeding	34.67[a]	1980.7[a]	40.47[a]	4.63[a]
	Row seeding	25.00[b]	733.2[c]	39.63[a]	3.73[b]
Autumn	Scatter seeding	32.67[a]	1703.8[a]	39.61[a]	4.17[ab]
	Row Seeding	22.33[b]	1097.5[b]	39.87[a]	3.61[b]

Means with the same letter are not significantly different according to Duncan's test P<0.05).

Discussion

The success of direct seeding in the natural resources area, especially under rainfed and cold weather conditions is usually affected by two main factors including the growing season precipitation and temperature, especially the occurrence of optimum temperature during the growing season. In other words, the emergence of seeds, the completion of vegetative growth, and the establishment of seedlings are the function of environmental factors beyond management control. Therefore, it must be admitted that research on rainfed sowing is associated with high risk and the expected outcome depends on the environmental conditions. In the study site, although the annual precipitation is above 300 mm, extreme environmental conditions such as minimum absolute temperature (-19°C in January 2008) and a relatively long glacial period (110 days) can change the predictions. The results on the establishment of *Astragalus lilacinus* showed that the establishment rate of this species under rainfed conditions was low (between 33.22 to 67.34% and an average of 28.5%); however, there is the possibility of seed emergence and establishment. It should be noted that seed vigor and viability after emergence are the other factors relevant to the success of such projects. An average viability of 35% was recorded for the collected seeds. After germination, the seedling survival is also a major issue, since soil moisture content cannot be controlled under rainfed sowing and is fully a function of environmental and climatic conditions. For the establishment rate, no significant difference was found between the sowing season (spring and autumn). It could be related to the proper precipitation during the growing season in the study area since the autumn cultivation is generally performed in regions where the spring precipitation is not adequate. However, there was a significant difference between the scatter and row seeding. The means comparison showed that the establishment rate was higher in the scatter seeding method than to row seeding. Because in scatter seeding, seeds were sown in soil surface. Therefore, in the case of row seeding, the sowing depth should be low and as much as three times the seed is larger in diameter for about three cm. Abtahi (2016) revealed that sowing depth was effective in survival rate of *Prangos uloptera* and a better result (73%) was obtained at a depth of 2.5 cm. For *Onobrychis melanotricha*, the highest survival (53%) occurred in the 1cm depth treatment (Abtahi, 2016). Therefore, strict observance of sowing depth can be effective in the emergence and establishment of species, and should be considered in all rangeland improvement and restoration projects. The plant height was affected by

the plant nature and environmental factors; therefore, the significant effect of year on the plant height and stems number indicates lower growth in the establishment year and the plant growth is increased in the following years in perennial species. Three studied traits as establishment, canopy cover and stem number were affected by the sowing method. The interaction effect of sowing method and sowing season was also significant for canopy cover. The highest canopy cover was obtained in the autumn seeding. Therefore, considering the importance of canopy cover percent in rangeland management, the scatter seeding in autumn could be recommended in the study area to obtain the highest canopy cover percent. Meanwhile, the effect of the year on each of the three traits was significant. In other words, sowing in a year with more precipitation and a more regular distribution as well as optimum temperature had a positive effect on all vegetative traits. However, the precipitation amount and distribution are not under management control, indicating the riskiness of rainfed sowing in rangelands. This result was similar to other research (Sharifi and Akbarzadeh, 2017). Therefore, in a rainfed sowing system, the moisture conditions and optimum temperature should be provided. The interaction effect of year, sowing date and method was not significant, but the effects of year and sowing method were significant.

Also, the combined effects of the year and sowing method were significant; therefore, the establishment of the study species depends on the sowing method and precipitation conditions of the planting year. Therefore, scatter seeding is the best method to establish in a year with good precipitation. However, sometimes due to the irregular precipitation distribution in spring, plants are exposed to drought stress in the spring sowing and in the last growth stage. Considering the mentioned issue and obtaining a greater canopy cover, the autumn sowing, as scatter seeding or row seeding, at a certain depth could be recommended. Canopy cover is the most important factor in rangeland improvement and rehabilitation (Bhattarai *et al*.,2008). Also, some studies have shown that canopy cover of the plant is effective in its production (Rosso *et al*., 1966) and (Piano *et al*., 1996). In a similar study, the effects of sowing season were evaluated on nine genotypes of two species of *Astragalus effusus* and *Astragalus brachyodontus* at the Homand Abrsard station. The results showed that the autumn sowing caused an increased production, height, canopy cover percentage, and stems number (Zarekia *et al*., 2016). This result is consistent with our findings on the canopy cover percent. The research results have shown that the autumn sowing is preferred as compared with the spring sowing in terms of germination and survival (Azhir and Fayaz, 2017) but in our study, we found no significant difference between two seasons.

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بررسی اثر فصل و روش کاشت بر استقرار و رشد رویشی گون علفی *Astragalus lilacinus* در استان اردبیل

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چکیده. امروزه در بحث اصلاح و توسعه مراتع انتخاب گونه مناسب، روش و زمان کاشت سه عامل مهم در موفقیت پروژه های اصلاح و احیا به شمار می‌روند. لذا بررسی اثرات زمان و روش‌های کشت در صفات رویشی و استقرار گونه *Astragalus lilacinus*، به منظور دستیابی به روش و زمان مناسب کشت در عرصه‌های طبیعی مرتعی استان اردبیل، از سال ۱۳۹۳ تا ۱۳۹۴ به اجرا در آمد. پس از جمع‌آوری بذر گونه از رویشگاه‌های طبیعی و آزمایش قوه نامیه، طرح آزمایشی به صورت کرت‌های خرد شده (اسپلیت پلات) در قالب طرح بلوک‌های کامل تصادفی با سه تکرار کشت شد. فاکتور A زمان کاشت (در دو سطح کشت پاییزه و بهاره) در کرت های اصلی و فاکتورB روش کشت (در دو سطح بذرپاشی و کشت ردیفی) در کرت‌های فرعی قرار گرفتند. کشت به صورت دیم در عرصه طبیعی انجام شد. پس از سبز شدن بذور و استقرار نهال‌ها، صفات درصد استقرار، درصد تاج پوشش، ارتفاع بوته و تعداد ساقه گلدار، در عرصه کشت به مدت دو سال اندازه‌گیری شدند. داده‌ها با استفاده از نرم افزارSAS تجزیه واریانس شدند و مقایسه میانگین به روش دانکن در سطح ۵٪ انجام شد. در مقایسه بین دو روش کاشت، میانگین درصد استقرار در روش کشت بذرپاشی (۳۳/۶) بیشتر از روش کشت ردیفی (۲۳/۶) بود. همچنین مقایسه میانگین اثر متقابل فصل کاشت در روش کاشت نشان داد که بیشترین عملکرد پوشش تاجی (۲۳۹۸ سانتی‌متر مربع) مربوط کشت پاییزه به روش بذرپاشی بود.

کلمات کلیدی: *Astragalus lilacinus*، اصلاح مرتع، کشت دیم، استان اردبیل