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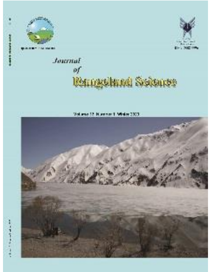

Research and Full Length Article:

Impact of Sowing Date on Growth, Phenology and Yield of Three Ecotypes of *Astragalus cyclophyllon* G. Beek in Semirom Rangelands, Iran

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Abstract. In order to compare the effect of sowing date on plant growth, development stages and forage yield of three *Astragalus cyclophyllon* G. Beek ecotypes, a study was conducted in 2010-2011 cropping years in Hanna station, Semirom county, Iran. Three *Astragalus* ecotypes were originated from Hanna, Golpayegan and Chadegan in Isfahan province, Iran. Seeds were sown in spring and autumn sowing dates using split plot design based on completely randomized blocks in three replications. The results showed that the effect of year was not significant, but the ecotype by sowing date interaction effect was significant on yield and yield components ($P<0.01$). The required temperature units such as Growth Degree Days (GDD) for spring and autumn sowing dates were 2848°C and 2793°C, respectively. The effect of sowing date on emergence percent and forage yield was significant ($p<0.05$). Regardless of the ecotype type, the percentage of seed germination and forage yield in autumn sowing were 51 and 60% higher than spring sowing date, respectively. The dry weight of Hanna ecotype in autumn cultivation was 1280 kg ha^{-1}, which was 55.8% and 58% higher than Golpayegan and Chadegan ecotypes, respectively. The reason for the increased yield in Hanna ecotype was of a higher ratio of its leaves. It was concluded that cultivation of Hanna ecotypes due to its higher forage production was recommended for cultivation in dryland farming and also to prevent its extinction in the study region.

Key words: Ecotype, Forage Yield, Growing Degree Days (GDD), Phenological Stages

Introduction

The phenology is defined as the plant biological stages that are affected by the environment upon occurrence (Lieth, 1974). Plant phenological growth stages can provide useful information for grazing management systems in the rangelands (Sadeghian *et al.,* 2004). Encountering the climate change through the present century has increased the importance of determining the suitable stages of plant growth for grazing (Chapman *et al.,* 2005). In fact, by recognizing phenological stages of the plant, it would be possible to establish a proper balance between the stages of plant growth and reproduction (Jalali *et al.,* 2017). Growing Degree Days (GDD) additionally has attempted to determine phenological stages of the plant (such as *Fritillaria imperialis*) growth (Zafarian *et al.,* 2019). The GDDs are also used to express the effect of temperature stress (cold or heat) on plant growth characteristics (Baghdadi *et al.,* 2013). A significant portion of Iran's livestock feed supplies is imported from abroad and the carrying capacity of the rangelands here in Iran cannot meet the animals' requirements and at the same time, the lower quality of forage do not let the animals fully exploit their growth and production potentials (Kamalzadeh *et al.,* 2008).

Astragalus cyclophyllon G. Beek is one good and palatable herbaceous species that grows in Iran’s semi-steppe rangelands and has an important role in fodder production for animals (Shahmoradi *et al.,* 2007). This plant also attracts numerous bees, because of its plentiful flowering and long term flowering period, and as a result, its produced honey has a favorable taste and color, which is very beneficial for beekeepers (Shahbazi *et al.,* 2017). The main habitat of this species in Iran is located in Hamedan, Kurdistan, Kermanshah, Isfahan, Chaharmahal-va-Bakhtiari, Kohkilooyeh-va-BoyerAhmad, Fars, Markazi and Lorestan (Moazam *et al.,* 2011). Alluvial plains of the Zagros mountain range from the altitude of 1900-2600 m above sea level are considered as natural habitats of *A. cyclophyllon*. This plant with the density of 678 to 4000 stands per hectare accompanies with species such as *Bromus tomentellus*, *Eurtia ceratoeides*, *Scuriola orientalis*, and *Stipa barbata* (Esmaeili Sharifi, 2000).

The seed dormancy and plant weakness establishment are presumed as the most important problems associated with its domestication and cultivation. The results of a study in Semirom region, Iran showed that the higher value (58.2%) of the seedling emergence was related to pitting seed sowing and the lower value (38.3%) was related to surface seed sowing. The investigation of the sowing season effect (spring and autumn) on nine genotypes originated from two species of *A. brachyodontus* and *A. effusus* in Alborz mountain slopes showed that the sowing season had a significant effect on forage production, plant height and crown coverage. The flowering stems number was higher in autumn than spring cultivation (Zarekia *et al.,* 2016). The protein content of *A. cyclophyllon* in flowering stage was 15.71% (Shahbazi *et al.,* 2017). Despite the considerable quantitative and the qualitative potential of this plant, its regeneration through seed is low. It is due to intensive livestock grazing would force the species' generation to undergo the extinction risk (Ghehsareh Ardestani *et al.,* 2014).

Considering the lack of sufficient information about the *A. cyclophyllon* phenological stages, the findings of this research could be useful for the management of conservation and protection of this rare species. The results also provide useful information for the domestication and cultivation of this plant as a rangeland plant. Consequently, the present study was aimed to evaluate forage yield, yield components and GDD requirement in phenological stages of *A.*

cyclophyllon in semi-steppe conditions of Iran.

Material and Methods

Laboratory operations were carried out in the seed technology analysis laboratory of Isfahan Agricultural and Natural Resources Research and Education Center, Isfahan, Iran. The field experiments were conducted at the Hana Natural Resources Research Station that is located at 40 Km of the Southeast of Semirom city (31.1989°N, 51.7250°E, elevation 2300 m) (Fig. 1). The mean temperature and precipitation statistics over two years of the research are shown in Table 1. Based on the Emberger climate classification, the climate of Semirom is defined as cold and Semi-dry. The station soil texture was silty loam (Esmaeili Sharif, 2000). Three ecotypes of *A. cyclophyllon* were collected from Semirom, Chadegan and Golpayegan rangelands (In the Isfahan province). The seeds of ecotypes were provided from seed bank of Isfahan Agricultural and Natural Resources Research and Education Center. The field experiment consisted of three ecotypes in two sowing seasons (spring and autumn) based on a completely randomized design with three replications.

The row spacing and a distance between the rows were designed as 50 cm and 40 cm, respectively. The area of each experimental plot was determined as 3 m^2 (2×1.5). Seedbeds were prepared and then, three seeds were sown in a hole with two cm soil depth (Esmaeili Sharif, 2000). The first fall and spring precipitation occurred after seed sowing was 15 and 22 mm, respectively. Maximum temperature during the growth period was recorded 17.4°C in June, and the minimum temperatures of autumn and spring sowing date were 10.2 and 10.8°C, respectively (Semirom Climatology Index, 2011).

The seedling sprouting date, primary leaves' emergence date, maximum vegetative growth time (beginning of flowering period), full flowering, seeding and shedding whole seeds were recorded during the field visit. The seedling emergence percent in experimental plots was counted and recorded during the first month on a daily basis. In each stage, the number and status of leaves and branches were investigated based on three plants per plot (Ping *et al.*, 2015). Following equation was used for the computation of GDD.

$$GDD = \left(\frac{T\max + T\min}{2} \right) - Tb$$

Where:
GDD = Growth Degree Day,
T max = daily temperature peak (maximum),
T min = daily temperature minimum and
Tb = the base temperature that was considered as 0.5°C for *A. cyclophyllon* (Xiaming *et al.*, 2012).

In our study, for the first time, the BBCH method was developed to express phenological stages of *A. cyclophyllon* (BBCH monograph, 2001). The extended BBCH-scale is a uniform coding system designed for phenologically similar growth stages of all mono and dicotyledonous plant species. It has been developed through the teamwork and interactions among German Federal Biological Research Centre for Agriculture and Forestry (BBA) and the Institute for Vegetables and Ornamentals in Grossbeeren/Erfurt of Germany (IGZ). The decimal code, which is divided into principal and secondary growth stages, is based on the well-known serial code developed by Zadoks *et al.* (1974) in order to avoid major changes from this widely used phenological key.

The BBCH method uses a decimal system as follows:

- Germination / sprouting / bud development (0);
- Leaf development (main shoot) (1);
- Formation of side shoots / tillering (2);
- Stem elongation or rosette growth / shoot development (main shoot) (3);

- Development of harvestable vegetative plant parts or vegetative propagated organs / booting (main shoot) (4);
- Inflorescence emergence (main shoot) / heading (5);
- Flowering (main shoot) (6);
- Development of fruit (7);
- Ripening or maturity of fruit and seed (8);
- Senescence, the beginning of dormancy (9).

To compare three mentioned ecotypes, some of their traits were measured in this study as follows:

1. Seedling emergence percent (the emergence of 50% of the plants per plot),
2. Canopy diameter (five plants were selected from each plot and their canopy's short and long diameters were measured),
3. The leaves number per plant
4. Forage Fresh yield was measured after removing the margin of 0.5 m from both sides of each plot.

Data analysis was performed to compare the effects of three ecotypes and two sowing seasons (spring and autumn) and their interactions for the forage yield, canopy cover, leaf number, and seedling emergence percent of *A. cyclophyllon* using SAS 9.1 statistical software (SAS Institute Inc., Cary, NC, USA). The data were checked for normalization and then, the means were compared using Duncan's Multi-Range Test ($p \leq 0.05$).

Table 1. Climate information of Shahid Hamzavi Hana station

Longitude (degree)	Latitude (degree)	Elevation (m)	Average Annual Temperature (°C)	Average annual maximum temperature (°C)	Average annual minimum temperature (°C)	Average annual Precipitation (mm)
51.70	31.15	2274	11.00	28.85	-6.85	317.00

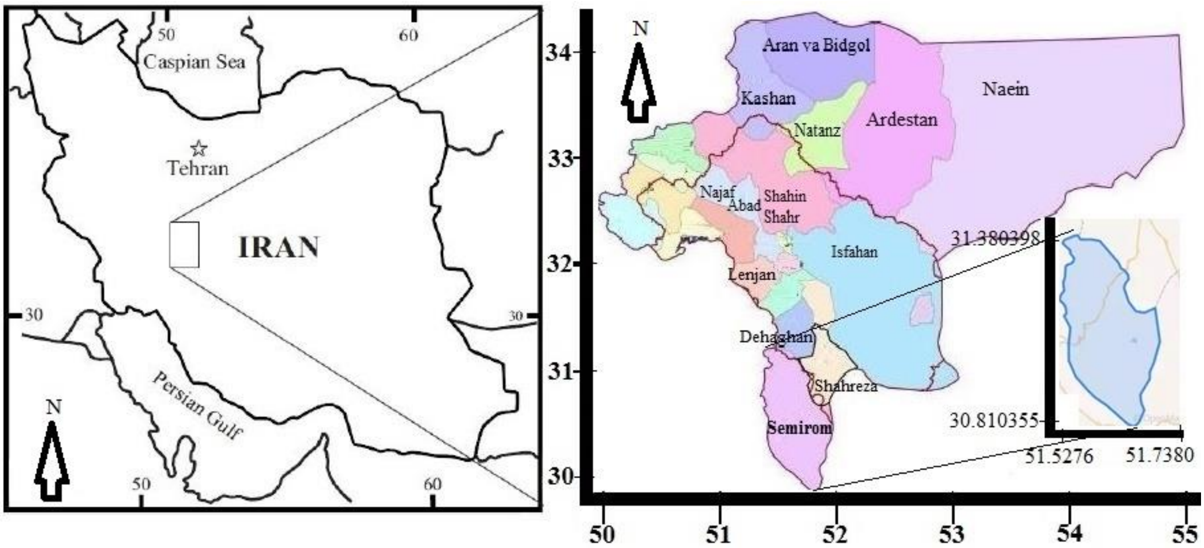

Fig. 1. The location map (study area) and habitat

Result and Discussion

Plant growth and developmental stages

The BBCH method was used to express phenological stages provided by German federal forestry and agriculture, biology research center. This manual has the unique power to make a rational relationship between the survey results. The present study was able to standardize these plant growth stages (Table 2).

According to the BBCH codding method, nine growth stages were considered for the *A. cyclophyllon* as the follows:

1-The main growth stage;
2-Germination and emergence;
3-Leave development;
4-Branching;
5-Main branch/ phylum lengthen;
6-Harvestable biomass production;
7-Bloom emergence;
8-Pods' growth and development;
9-Pods' maturation and aging.

These stages were carefully recorded. Each of these nine stages was divided to minor stages as well (Fig.2). Some considerations in steps' coding procedure were:

The growth stages 17-19 were occurred along with the plant phenological growth stages of 21 to 23 and 91 to 93 simultaneously.

Simple cotyledon leaves were mutual and had a heart shape. The subsequent leaves were compound and periodic with three and five leaflets. The leaves' numbers were counted instead of the node numbers.

The growth stages of 26-28 were simultaneous with the bloom (bud) emergence (growth stages 51- 53).

After branching termination (29), the blooms opened or the plants blossomed (Growth stage 60). The height of the main branch in the *A. cyclophyllon* reached up to 50% of the final length in growth stage 51 and this lengthened the continuation of the flowering up to 30% (growth stage 63).

The growth stages 47- 49 were simultaneous with the growth stages 62-65. The most fodder' yield was obtained in stage 67 (opening 70% of the flowers). The blooms were very small and elliptical so that their sight in the main growth stage 50 (transient stage from vegetative to generative or flower bloom emergence stage) was very difficult. Its inflorescences began to expand about a month before the flowering began when the daylight length exceeds 17 hours that was accompanied with the sudden emergence of several bloom sets (52). The growth stages indicated 67-69, simultaneous with the growth stages 72, 73 and 74, respectively.

The growth stage 85 was concurrent with reaching to maximum sheath length (growth stages 77-79). Many researchers have used growth phenological stage preparation by the BBCH method for the expression and interpretation of various yields and determining damages caused by live and non-live stresses (Meier *et al.*, 2009).

Table 2. The *A. cyclophyllon* growth and development of phenological stages using the coding system

Description of Main Growth:	Code
Stage 0: Germination and emergence	
0	Dry seeds
1	The beginning of imbibition
3	The seed complete imbibition
5	The Exit of the root from the seed
6	Extension of the root, lateral root and the capillary formation
7	The Exit of stems and cotyledons from the seed cover
8	Growth of the stems and cloves from the seed coat to the soil surface
9	Emergence: The commencement of cotyledons' removal from the soil surface
Stage 1: Leaves Development	
10	Complete opening of cotyledons and initiation of photosynthetic activity of the cotyledon leaves
11	The appearance of the first true leaf (composite)
12	The appearance of the second true leaf (composite)
13	The appearance of the third true leaf (composite)
14	The appearance of the fourth true leaf (composite)
15	The appearance of the fifth true leaf (composite)
16	The appearance of the sixth true leaf (composite)
17	The appearance of the seventh true leaf (composite)
18	The appearance of the eighth true leaf (composite)
19	The emergence of the ninth leaf and the next leaves (composite)
Stage 2: Branch	
20	Unplugged the branch in the bush
21	Viewing the first branch
22	Viewing the second branch
23	Viewing the third branch
24	Viewing the fourth branch
25	Viewing the fifth branch
26	Viewing the sixth branch
27	Viewing the seventh branch
28	Viewing the eighth branch
29	Finishing branching: Creating 9 or more branches near the crown
Stage 3: Elongation of main branch	
31	The main branch elongation up to 10% of the final length
32	The main branch elongation up to 20% of the final length
33	The main branch elongation up to 30% of the final length
34	The main branch elongation up to 40% of the final length
35	The main branch elongation up to 50% of the final length
36	The main branch elongation up to 60% of the final length
37	The main branch elongation up to 70% of the final length
38	The main branch elongation up to 80% of the final length
39	The main branch elongation up to 90% of the final length
Stage 4: Growth and development (Yield)	
41	10% of the final weight of the harvestable forage
43	30% of the final weight of the harvestable forage
45	50% of the final weight of the harvestable forage
47	70% of the final weight of the harvestable forage
49	90% of the final weight of the harvestable forage
39	The main branch elongation up to 90% of the final length
Stage 5: Rising the flower bud	
51	10% of the final weight of the harvestable forage
52	70% of the final weight of the harvestable forage
53	90% of the final weight of the harvestable forage
Stage 6: Flowering	
60	Opening the first flowers
62	Opening 20% of the flowers
63	Open 30% of the flowers
64	Opening 40% of the flowers
65	Full flowering: opening 50% of the flowers
67	Flower Decline: Opening 70% of flowers, and beginning to form the pods
69	End of flowering
Stage 7: Growth of the pods	
71	10% of the pods have reached the final length and brown color.
72	20% of the pods have reached the final length and brown color.

Description of Main Growth:	Code
73	30% of the pods have reached the final length and brown color.
74	40% of the pods have reached the final length and brown color.
75	50% of the pods have reached the final length and brown color.
76	60% of the pods have reached the final length and brown color.
77	70% of the pods have reached the final length and brown color.
78	80% of the pods have reached the final length and brown color.
Stage 8: Maturity	
Stage 9: Senescence	

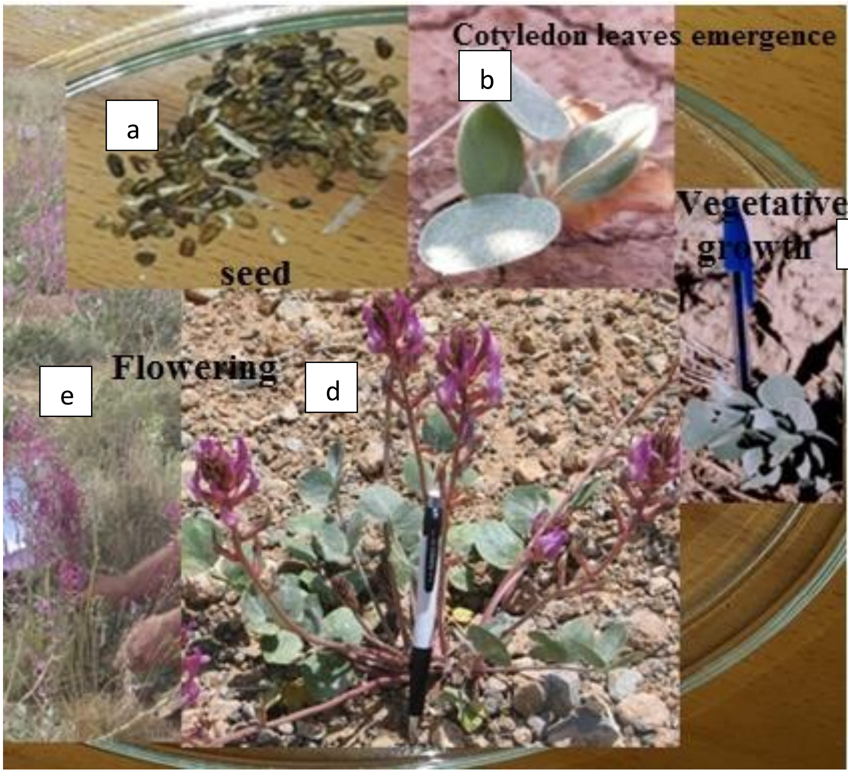

Fig. 2. Different growth stages. a) seed sowing (00) b) complete opening of cotyledons and the initiation of photosynthetic activity of cotyledon leaves (10) c) appearance of the third true leaf (composite) (13) d) opening the first flowers (60) e) full flowering: opening 50% of the flowers (65)

Estimation of GDD values

The GDD values for phenological stages of the *A. cyclophyllon* in spring and autumn seasons in Semirom region are presented in Table 3. Since, the short term statistics are not sufficient for determining plant temperature requirement, daily statistics of the region during a period of 15 years were used to identify plant temperature requirement through various growth stages. The GDD of 2848°C is needed for the completion of plant growth stage in *A. cyclophyllon* spring sowing date (Table 3). Approximately, 70% of this requirement is needed over the time interval of the pod growth and development up to plant aging. This duration is simultaneous with the region maximum temperature that may be observed in the study area. In autumn cropping, two different conditions can be seen. a) Due to the coldness and the characteristics of the seed shell, the plant enters to the dormant period. b) In these circumstances, the conditions like spring appear and temperature requirement would also be similar to spring one.

The *A. cyclophyllon*'s has pretty long vegetative growth period length that is considered as its strength in providing fodder and it was greatly associated with regional climate conditions (Najafi Tireh Shabankareh, 2004). In a study implemented on three species, *A. podolobus*, *A. caragana*, *A. cyclophyllon* in the central zone of Iran, Ardestani *et al.*,

(2015) showed that in the west and the south west zones of Isfahan province, particularly the regions with a high altitude of 2200-3000 m coupled with temperature lower than 3°C had an appropriate condition for developing and extending the cultivation of these three species. Our study showed that in Isfahan province, there are excellent, good and medium areas for cultivation of the *A. cyclophyllon* species and the coverage in mentioned three regions was equal with 4.39%, 8.86% and 19.35%, respectively.

In the second situation, seeds emergence percent was high in autumn due to temperature requirement provided at this time. Such a situation was similar to the second year of the study. In this case, nearly 136 thermal units were absorbed by the plant from the middle to the late of November and plant's growth was started earlier than spring. Although the plant's primary stabilization in such condition is better in spring than the autumn, along with the time elapse, significant differences were not observed between spring and autumn sowing concerning thermal unit. For autumn sowing date, the total GDD needed for completion of the plant growth was 2793°C units. Plant's different behavior in autumn sowing date was attributed to seed traits and seed coat. The germination speed of the *A. cyclophyllon* seeds is relatively slow and using of some material like Gibberellic acid (500 mg/l), or sulfuric acid was not more effective on seed germination (Sabeti *et al.,* 2019; Keshtkar *et al.*, 2008).

Table 3. Main phenological stages and temperature requirement Growing Degree Days (GDD) of the *A. cyclophyllon* in spring and autumn sowing season

Phenological stages	Spring		Autumn	
	Date	(GDD)	Date	(GDD)
Stage 0: Germination and emergence	Mar 10 to 15th	43.51	Nov 5 to 20th	136.38
Stage 1: Leaves development	Mar 15th to Apr14th	52.98	Feb 20th to Apr 1st	52.00
Stage 2: Branching	April 5th to May 1st	256	Apr 1st to Apr 20th	135.5
Stage 3: Elongation of main branch	Apr 10th to May 10th	126	Apr 1st to May 1st	163.13
Stage 4&5: Growth & Development	Apr 10th to May 20th	207	Apr 1st to May 10th	154/04
Stage 6: Flowering	May 5th to Jun 1st	209	Apr 21st to May 22nd	225.76
Stage 7: Growth of pods	May 20 to Jun 20	493	May 12th to Jun 11th	451.00
Stage 8: Pods' Maturity	May 26th to July 8th	444	Sept 20th to Jul 12th	527.47
Stage 9: Senescence	Aug 1st to Aug 15th	1017	Jul 26th to Aug 8th	947.76
Total		2848		2793.04

The Effect of sowing seasons on yield and yield components

Bartlett's test was performed to examine the homogeneity of error variance and due to the fact that the year's effect was not significant; therefore, the year effect were not considered. However, the sowing date by ecotype interaction effect was significant for all of the traits (Table 4). Due to higher precipitation in the second year (more than 315 mm), it was expected that the higher production obtained in the second year. It should be noted that almost all extra precipitations occurred in November and December. Such precipitation in autumn accelerated primary emergence and as a result, it facilitated the dormant period entrance; therefore, its effects cannot be considered the same as spring precipitation. In general, the temperature during April to November in the first year of the study was rather lower than the long term period; however, the approximate agreement was observed between two statistics. The mean precipitation during the first year from October to March was lower than the long term precipitations. Of course; such conditions were expected considering the latest year drought.

The result of means comparison of seedling emergence percent of three *A. cyclophyllon* ecotypes indicated significant differences ($P<0.01$) (Table 4). In autumn cultivation, the Hana ecotype had higher seedling emergence with values of 64% and 68% than Golpayegan and Chadegan ecotypes, respectively. A similar trend was observed in spring sowing date; however, regardless of ecotype kind, the seedling emergence percent in autumn was 51% higher than spring sowing date. Despite the superiority of Hana ecotype, its seedling emergence percent was relatively low with average values of 22% and 18% in autumn and spring sowing date, respectively. Moshtaghyan *et al. (*2009) in a research conducted in Semirom rainfed condition showed that the seedling emergence' percent of *A. cyclophyllon* was 38 to 58%. Specific characteristics of the seed coats, leading to seed dormancy that could be the main reason for the low seed germination rate of this species. It seems this phenomenon is common in other *Astragalus* species (Keshtkar *et al.,* 2008). The thick pectin layer of the seed coat prevents the humidity penetration into the seed and decreases the germination percent (Wang, 2009). As Bushman *et al.* (2015) has reported, the rangeland legumes' species utilize alternate germination techniques for their survival in difficult conditions.

Hana ecotype in autumn sowing date had 1280 kg h^{-1} yield which was 56% and 58% higher than Golpayegan and Chadegan, respectively; however, no significant differences were found between Golpayegan and Chadegan (Table 5). The similar trend was observed in spring sowing date. Regardless of the ecotype, the yield of *A. cyclophyllon* in autumn sowing date was 60% higher than its yield in spring date. The total seasonal precipitation was 316 mm in the present study. In dry land farming system, forage yield of the rangeland depends entirely on the rainfall amount and distribution. For example, in a three-year survey in Damavand region, Iran, the precipitations of 341, 339, and 370 mm were recorded and a Isfahan originated ecotype of *A. cyclophyllon* had 45, 66,194 kg ha^{-1} production, respectively. In contrast, forage yield of Kurdistan ecotype of the *A. vegetus* was 1385 kg h^{-1} (Zarekia *et al.,* 2014). In the similar study, the effect of sowing season (spring and fall) on nine genotypes of the two species of the *A. brachodontus*, *A. effusus* in the southern slopes of Alborz mountain showed that the sowing date had a significant effect on forage yield and higher values were obtained in autumn sowing date than spring (Zarekia *et al.,* 2016).

The high yield of Hana ecotype was associated with its more leaves in both spring and autumn sowing dates (Table 5). The Hana ecotype leaves' number in autumn sowing date was 3 and 1.8 times higher than Golpayegan and Chadegan ecotypes, respectively. The leaves number and the leaf to stem ratio has a significant effect on crude protein percent (Shahbazi *et al.,* 2017). The plant crown coverage diameter that has a direct relationship with the plant leaves number was 350 and 170 mm^{-2} in Hana ecotype in spring and autumn sowing dates, respectively (Table 5). Golpayegan ecotype had the lowest crown diameter. As a fact, the vegetation represents the plant's capacity to properly absorb the light energy and sometimes, it is used as an indicator for the soil conservation (Zarekia *et al.,* 2016).

Table 4. Result of analysis of variance sowing date, ecotypes on seedling emergence percentage, leaves' number, canopy coverage, and forage yield over two years in

Source of Variation	DF	MS			
		Seedling Emergence	Canopy cover diameter	Leaves Number	Forage Yield
Sowing date (D)	1	1236.19 *	1145.77 *	1032.99*	1108.12 *
Ecotype (E)	2	2067.00 **	1769.04 **	1978.00 **	2222.00 **
D × E	2	3009.17 **	2004.34 **	2345.14 **	3196.14 **
Error1	8	824.30	487.60	567.60	724.10
Year	1	756.23 n.s	511.65 n.s	567.03 n.s	606.13 n.s
Year × D	1	600.55 n.s	571.39 n.s	261.35 n.s	578.45 n.s
Year × E	2	789.21 n.s	609.77 n.s	641.79 n.s	734.27 n.s
Year × D × E	2	658.11 n.s	543.56 n.s	487.16 n.s	701.10 n.s.
Error2	18	976.8	605.12	765.45	805.70

n.s, * and **: Not significant and significant at p≤0.05 and p≤0.01, respectively.

Table 5. The comparison of yield, emergence percentage, leaves number, crown coverage diameter of the *A. cyclophyllon* in spring and autumn sowing date

Ecotypes	Emergence (%)		Canopy Diameter (mm)		Leaves No/plant		Forage Yield (Kg h^{-1})	
	Autumn	Spring	Autumn	Spring	Autumn	Spring	Autumn	Spring
Hanna	22 a	18 a	350 a	360 a	45 a	29 a	1280 a	800 a
Golpayegan	14 b	3 b	40 c	50 c	15 c	3 c	715 b	337 b
Chadegan	15 b	5 b	140 b	170 b	25 b	23 b	743 b	497 b
Average	17 A	8.7 B	177 A	194 A	28.4 A	18.4 B	912.7 A	544.7B

Different letters in each column for each sowing date indicate the significant difference at p≤0.05.

Conclusion

Concerning the novelty of the study, as it was indicated earlier, the current research focused on *A. cyclophyllon* species in Semirom rangelands for the first time and its findings can be summarized in two different sections as below: 1) the standardization of phenological growth stages, and 2) the fodder production. The identification of plant growth and development stages based on standard method provides the proper conditions for investigation of rational relationships among various studies. The results of this study showed that the *A. cyclophyllon* growth and development stages are divided into nine stages based on the BBCH method. Each of these stages had sub-sections in a way that the present complete description of plant growth and development could be generalized to them as well.

Optimal use of water sources for crop production is a reasonable approach under the drought conditions. The *A. cyclophyllon* is a kind of rangeland species that has dry farming cultivation capability. Hence, it is not only preserved in its main habitat, but also the seed bed is appropriately prepared for the production of high quality fodder. The results of this study showed that the *A. cyclophyllon* cultivation, especially in autumn season can be successfully done in Semirom region (and the regions with similar conditions) to produce acceptable fodder. Likewise, the Hana ecotype was identified as a superior and highly productive ecotype in both spring and autumn sowing dates.

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فنولوژی رشد و عملکرد سه اکوتیپ گون علوفه‌ای *Astragalus cyclophyllon* G. Beek تحت تأثیر تاریخ کاشت در منطقه سمیرم

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چکیده. به منظور مقایسه تاثیر تاریخ کاشت بر مراحل رشد و نمو و عملکرد سه اکوتیپ گون علوفه‌ای *Astragalus cyclophyllon* ، پژوهشی در سال‌های زراعی ۱۳۹۰-۱۳۸۹ در منطقه حناء شهرستان سمیرم انجام شد. سه اکوتیپ گون شامل حناء، گلپایگان و چادگان در دو تاریخ کاشت بهاره و پاییزه با طرح پایه‌ی بلوک‌های کامل تصادفی در سه تکرار کشت شدند و داده جمع آوری شده در دوره دو ساله با استفاده از طرح کرت‌های خرد شده تجزیه واریانس شد. نتایج نشان داد تأثیر سال بر صفات آزمایشی از نظر آماری معنی‌دار نبود امّا برهم‌کنش تاریخ کاشت و اکوتیپ بر عملکرد و اجزای عملکرد معنی‌دار شد ($p<0.01$). در کشت بهاره و پاییزه گون علوفه‌ای به ترتیب به ۲۸۴۸ و ۲۷۹۳ درجه روز رشد (GDD) برای تکمیل دوره رشد گیاه نیاز داشتند. نتایج نشان داد که تأثیر تاریخ کاشت بر درصد سبز شدن و عملکرد علوفه معنی‌دار بود ($p<0.05$). صرف‌نظر از نوع اکوتیپ، درصد سبز شدن بذور و عملکرد علوفه در کشت پاییزه به ترتیب ۵۱ و ۶۰ درصد از کشت بهاره بیشتر بود. عملکرد اکوتیپ حنا در کشت پاییزه معادل ۱۲۸۰ کیلوگرم علوفه خشک در هکتار بود که نسبت به دو اکوتیپ گلپایگان و چادگان به ترتیب ۵۵/۸ و ۵۸ درصد افزایش عملکرد داشت. عملکرد بالای اکوتیپ حنا با تعداد برگ بیشتر در مراحل رشد و نمو همراه بود. بر اساس نتایج بدست آمده کشت دیم اکوتیپ حناء در منطقه سمیرم نه تنها می‌تواند علوفه مناسبی تولید نماید بلکه خطر انقراض این گونه را نیز در منطقه مرتفع می‌سازد.

کلمات کلیدی: اکوتیپ، عملکرد علوفه، درجه روز رشد (GDD)، مراحل رشد فنولوژیکی