Journal of Natural Resource Conservation and Management
Vol. 1, No. 2, pp 125-130, 2020
doi: 10.51396/ANRCM.1.2.2020.125-130

Forage resources in arid and saline environments of central Iran: production potential and phenology of *Alhagi maurorum*

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Received : October 29, 2020
Revised : December 2, 2020
Accepted : December 7, 2020
Published : December 23, 2020

ABSTRACT

Although significant amount of information is available on camelthorn (*Alhagi spp.*) as a weed, little is known about *Alhagi spp.* as a forage plant. Considering its forage value, the present study was conducted to document the phenology and biomass production of *Alhagimaurorum*Medik.in two dry saline rangelands of Ashkezar and Ardakan regions at central Iran during 2019. The results distinguished seven stages for *Alhagi*, consisted of shoot emergence, main stem growth, branching, budding, flowering, fruiting, and seed ripening occurred after 22, 30, 78, 41, 54, 61 and 118 days in Ashkezar region and 31, 37, 67, 33, 41, 50 and 106 days in Ardakan, respectively. Depending on the region, *Alhagi* germinates and grows in mid to early February, and the main stems started to grow in late February to early March, and the branches were formed in mid to late March. Flowers appeared in mid-to-late April, while fruits in early May to early June. Finally, the seeds began to ripen from late May to mid-June. Senescence also occurred in late summer and early autumn at the latest. Anyway, in the saline and arid conditions of these two regions, *Alhagi* completed the life cycle and produced an average of 1404 and 280 g m^{-2} of fresh and dry weight, which was significant for a rangeland plant. Due to the relatively high shoot moisture (about 80%) the quality of forage produced can be considered as acceptable for animal feed. Therefore, *Alhagi* can be considered as an alternative option for forage production in saline environments with limited freshwater resources.

Keywords: Drought, halophyte, rangeland, salinity, xerophyte.

INTRODUCTION

Phenology is a method of quantifying plant life cycle, which is defined as the timing of seasonal life cycle events in plants. Plant phenology is influenced by the regional environmental conditions (Browning *et al.*, 2019), and varies between different species of the same genus. Environmental factors such as temperature and rainfall most important factors that affect the plant phenological changes. Plant phenology is important for the life cycle of plants, as it governs many crucial plant functions such as growth, production, quality and ecosystem sustainability (Enquist *et al.*, 2014).

In rangelands producers and researchers need updated, timely, accurate, reliable, and interpretable information for better managing rangelands (Browning *et al.*, 2019). Reliable predictions of rangeland productivity are important components for soil and water resource planning that are closely related to the plant phenology (Hufkens *et al.*, 2016).In particular, phenology significantly affects the forage quality of rangeland plants; and in most species, the highest quality is obtained in the vegetative stage.

Camelthorn (*Alhagi spp.*) is one of the rangeland plants that can potentially be considered as a forage plant. *Alhagi* can be found in dry, rocky, and saline soils; which are currently found in all temperate and tropical regions of the world(Pirasteh-Anosheh, 2020). Salinity is one of the most important abiotic stresses adversely affecting the overall metabolic activities and cause plant demise. The global extent

of salt affected area is about 955×10^6 ha (Singh *et al.*, 2020). The germination usually takes place in spring and flowering in summer, with flowering time and length varies with the regions and growth conditions (Nikfam *et al.*, 2013). Due to its perennial nature and wide distribution, *Alhagi* helps retain sand dunes and prevents soil erosion. *Alhagi* leaves are also grazed as forage by livestock, especially camels and goats (Jiang *et al.*, 2014).

Alhagi has long been considered a dangerous weed, and much research has been done on this plant from this perspective (Nikfam *et al.*, 2013; Pirasteh-Anosheh, 2020). However, little research has been done on *Alhagi* as a forage plant (Jiang *et al.*, 2014; Jin, 1994; Weber and Hanks, 2006). Studies have shown that *Alhagi* is a plant tolerant to both the salinity and drought stresses, and it has also been reported that mild levels of salinity or drought stresses limits the plant growth, however these are required for simulating the early growth (Weber and Hanks, 2006). Therefore, different species of *Alhagi* can be considered as a rangeland forage plant. More researches are needed to enhance growth in agriculture and natural resources by increasing resource use efficiency, minimizing effects on environment, and integration with natural biogeochemical cycles to minimize inputs (Bhardwaj *et al.*, 2020). The first step in entering a new plant into the production cycle is to know all aspects of life. Therefore, in the present study, *Alhagi maurorum* phenology was investigated in two saline and dry rangelands in central Iran.

MATERIALS AND METHODS

The present study was conducted to investigate the phenology of *Alhagi maurorum* Medik. in two saline and dry rangelands in the center of Iran in 2019. The first rangeland was in Ashkezar and the second was in Ardakan, both are located in Yazd Province (Figure 1). Some properties of the two surveyed regions are presented in Table 1. With the beginning of the *Alhagi* life cycle from mid-winter, all stages of life were recorded. The studied plants were perennials that grew from the rhizomes. To do this, three quadrats of 24 square meters (4 ×6 m) were identified in each region that had a good density and almost uniform distribution. Each of these areas was considered as a plot (replication). The criterion for each stage was the entry of 50% of the plants of each plot to that stage. Seven phenological stages were determined for the evaluating the *Alhagi* phenology consisted of shoot emergence, main stems

Figure 1. Geographical location of the surveyed regions

Table 1. Some specifications of the studied areas

Region	Latitude (° N)	Longitude (° E)	Height (m asl)	Soil EC (dS m^{-1})	Soil pH
Ashkezar	32.052	54.236	1135	25.3	7.15
Ardakan	32.510	53.884	979	36.2	7.81

growth, sub-branching, budding, flowering, fruiting, and seed ripening.

We found out of about 16 *Alhagi* species, six species are more important in terms of the distribution and growth. These six species are: 1) *A. maurorum* Medik., 2) *A. graecorum* Boiss., 3) *A. canescens* (Regel) Shap., 4) *A. kirghisorum* Schrenk, 5) *A. nepalensis* (D. Don) Shap. and 6) *A. sparsifolia* Shap. It should be noted that *persarum*, *camelorum*, *pseudalhagi* are the synonyms of *maurorum*, and *graecorum* is the synonym *mannifera*. Two important species in Iran are *A. maurorum* and *A. graecorum*. The *graecorum* is shorter than *maurorum*, has denser thorns, a fully serrated sepal, a fruit covered with compact hairs, and a finely rosary pod.

At the end of the growing season, one square meter of plants was completely harvested from each plot, and their weights were measured as fresh weight. The weight of the samples was considered as the dry weight for 48 hours after being placed in a 70±2°C oven. A soil sample was taken from each plot and the electrical conductivity of saturated extract (EC_e) and pH were determined.

Data analysis included analysis of variance (ANOVA) and mean comparison (T-test or standard error), which were performed using SAS software.

RESULTS AND DISCUSSION

In the two regions, despite the high salinity and drought, *Alhagi* was able to grow and complete its life cycle with seed production indicating its high tolerance to salinity and drought (Figure 2). *Alhagi maurorum* grows in saline meadows, which mainly present at the end of watersheds and could supply forage in spring even though the species is thorny in nature (Weber & Hanks, 2006). The rapid growth and high rate of photosynthesis allow *Alhagi* to grow and produce biomass in saline and dry environments (Bazoubandi *et al*., 2006; Pirasteh-Anosheh, 2020). Soil moisture mediates the effects on the structure and function of ecosystems by regulating the rates of photosynthesis and transpiration (Bhardwaj *et al*., 2020).

The life cycle of *Alhagi* in the two studied regions started from late winter (Figures 3 and 4). In Ashkezar and Ardakan, the first seedlings emerged

Figure 2. Some photo of *Alhagi maurorum* Medik. grown in a hyper-saline desert in Ardakan, Yazd (These photos were taken in the surveyed region, but not in the experimental plots.)

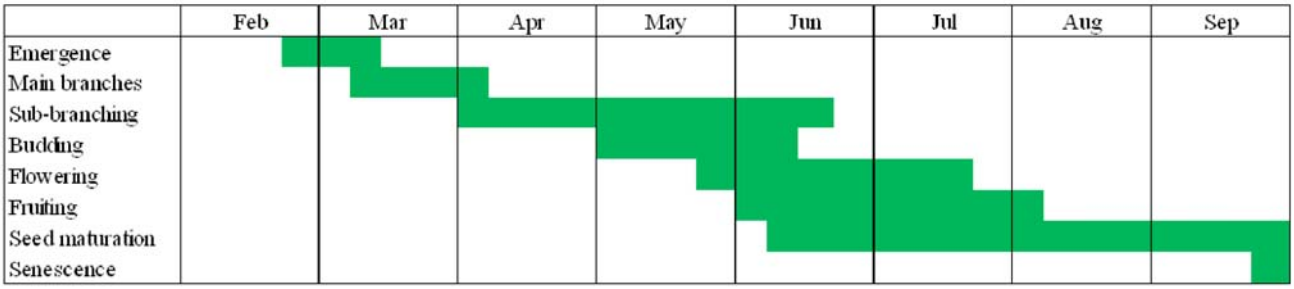

Figure 3. Phenology of *Alhagi maurorum* in Ashkezar, Yazd

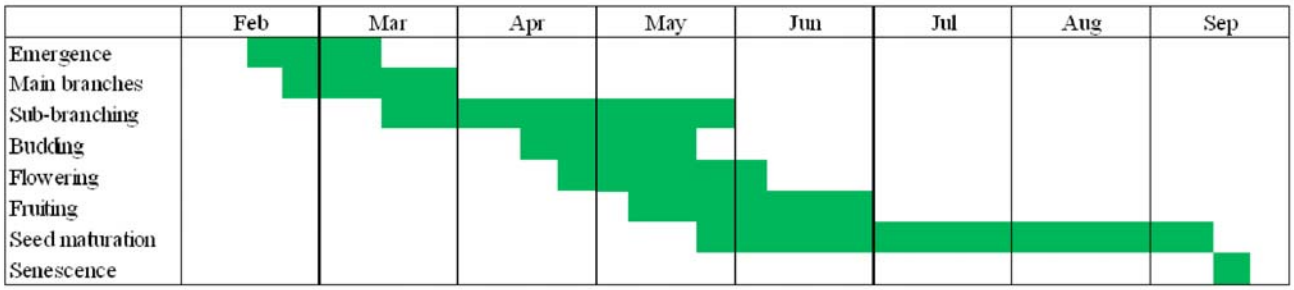

Figure 4. Phenology of *Alhagi maurorum* in Ardakan, Yazd

from the rhizomes on the ground from late and mid-February, respectively. In Ashkezar, the main stems started to grow from mid-March and the sub-branches from early April (Figure 3). The growth of main stems and sub-branches in Ardakan started from late February and mid-March, respectively (Figure 4). Budding in these two regions occurred in early May and mid-April, respectively. In Ashkezar, flowering began in late May, fruiting in early June, and seed ripening in early-mid-June. In Ardakan as well; these phenological stages began in early May, mid, and late May, respectively. The end of the growing season in Ashkezar and Ardakan was late and mid-September, respectively. Phenological patterns for rangeland species may have more important implications than crop species for how they are managed in order to prevent them from emerging as an invasive plant (Browning *et al.*, 2019).

In Ashkezar, the first seedlings appeared on the ground on February 23, and the germination phase took about 22 days (Table 2). Before the completion of emergence, the formation of the main stems began on March 7 and lasted for about 30 days. Sub-branches were formed on March 29, and new branches continued to form for at least 78 days. Buds and flowers appeared on April 28 and May 22, respectively, and lasted until 41 and 54 days, respectively. Fruiting of *Alhagi* plants started on June 2 and continued for 61 days. In Ardakan, the first shoots sprouted on February 15, and new shoots

Table 2. Properties of the phenological stage of *Alhagi maurorum* in two regions

Stage	Yazd		Ardakan	
	Beginning time	Duration (days)	Beginning time	Duration (days)
Emergence	23-Feb	22.3 [b]	15-Feb	31.0 [a]
Main stems grow	07-Mar	30.6 [b]	22-Feb	37.0 [a]
Sub-branching	29-Mar	78.0 [a]	13-Mar	67.6 [b]
Budding	28-Apr	41.0 [a]	15-Apr	33.3 [b]
Flowering	22-May	54.3 [a]	23-Apr	41.3 [b]
Fruiting	02-Jun	61.6 [a]	09-May	50.3 [b]
Seed ripening	08-Jun	118.0 [a]	23-May	106.0 [b]
Senescence	29-Sep	11.6 [a]	17-Sep	9.6 [b]
Whole growing season		219		215

Means were separated in each row by T-Test.All stages overlapped in time.

appeared for about 31 days. The formation of the main stems began on February 22 and lasted for about 37 days. From March 13, new branches were formed for 67 days. Budding and flowering occurred from April 15 and 23, respectively, and lasted about 33 and 41 days, respectively. The fruiting stage in *Alhagi* began on May 9 and lasted up to 50 days. The longest growing period was in both seed ripening areas (Table 2). In Ashkezar and Ardakan, the seeds started to ripen on June 8 and May 23, respectively, and lasted about 118 and 106 days, respectively. A previous research has also reported that the shortest and the longest phenology period of *Alhagi* referred to budding and seeding by 22 and 90 days, respectively (Nikfam *et al*., 2013). Maraki *et al*. (Maraki *et al*., 2016) reported that the durations of these two stage were 23 and 74 days, respectively. Plant phenology can be important for the natural resource managers to monitor species production for grazing management by using the online tools. This helps to use the forage at the best quantity and highest quality considering the sustainability of the environment (Hufkens *et al*., 2016). However, salinity and drought might also affect the phenology of species in term of occurrence and senescence as same conditions may be applicable to *Alhagi*. Based on the estimation, threshold salinity tolerance of *Alhagi is* about 15 dS m^{-1} (Amiri *et al*., 2012; Zeng *et al*., 2008), moreover, at higher salinities, germination of *Alhagi* does not stop completely but seeds keeps on germinating (Zeng *et al*., 2008).

The results showed that the total growth period was about 219 days in Ashkezar region and about 215 days in Ardakan region (Table 2). Previous findings have also reported that the growth cycle of *Alhagi* is about 200-211 days which is equal to 3503-4049 growth degree days (Nikfam *et al*., 2013). However, Maraki *et al*. (Maraki *et al*., 2016) indicated that the duration of all the phenological stages of *Alhagi* lasted for 189 days.

The fresh and dry weight of *Alhagi* shoot was higher in Ashkezar region than Ardakan region (Figures 5 and 6). *Alhagi* plants in Ashkezar had 45.2% and 11.3% more fresh and dry shoot weight, respectively, compared to Ardakan region. This difference is probably related to the soil salinity and acidity as two regions approximately receives similar precipitations and experience same air temperature. As given in results that Ashkezar had lower soil salinity and pH than Ardakan (Table 1). *Alhagi*is a xerophyte and a facultative halophyte in the early growth and germination stages (Amiri *et al*., 2012). It was reported that *Alhagi* species is more tolerant to salinity compared to *Salicornia* species at the vegetative stage (Amiri *et al*., 2012).The extensive and advanced root system absorb water from very deep depths which makes *Alhagi*as highly tolerant to drought stress (Jin, 1994).

The amount of fresh forage production in Ashkezar and Ardakan was 1.66 kg m^{-2} and 1.15 kg m^{-2}, respectively (Figure 5). Similarly, *Alhagi* plants in saline and dry conditions of Ashkezar and Ardakan were able to produce 295 and 265 g m^{-2} of dry forage, respectively (Figure 6). Although these values may not be high compared to the cultivated forage crops, however as a rangeland crop, they are very significant numbers and can be very important in saline conditions with limited water resources where agricultural activities cannot be undertaken. The moisture content of *Alhagi* shoots in Ashkezar

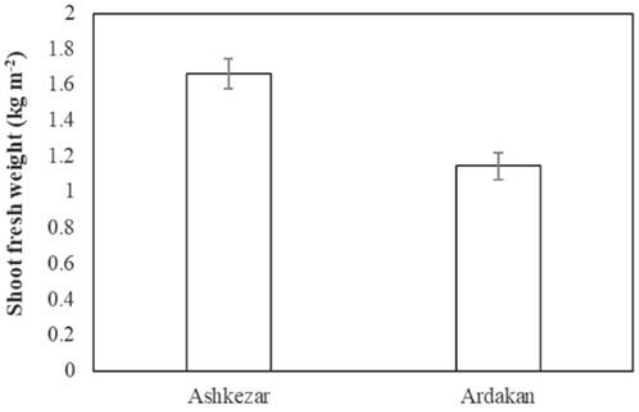

Figure 5. Shoot fresh weight of *Alhagi maurorum* in two surveyed regions. The columns with similar overlap have no significant difference based on standard error (±SE)

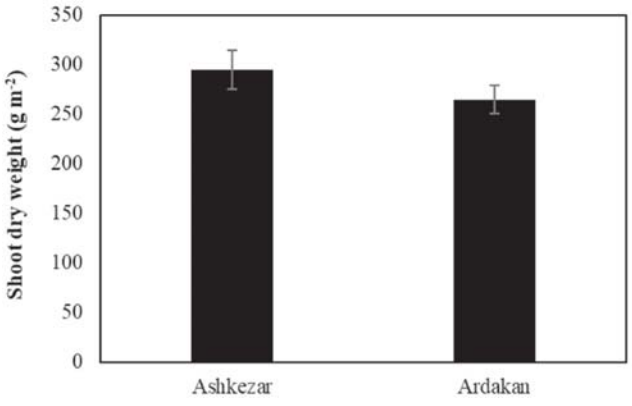

Figure 6. Shoot dry weight of *Alhagi maurorum* in two surveyed regions. The columns with similar overlap have no significant difference based on standard error (±SE)

(82.3%) was significantly higher than Ardakan (76.9). *Alhagi* is more suitable than many common forages such as cereal straw and even comparable to clover and alfalfa in terms of crude protein content (El Shaer, 2010). It has been shown that among the plants tolerant to salinity, *Alhagi* is one of the most palatable plant species for camels and sheep (El Shaer, 2010; Weber and Hanks, 2006).

CONCLUSION

In general, *Alhagi* emerges in February, grows vegetatively in March and April, and reproduces in May, June, and July months. The seeds ripen during the months of June to September. *Alhagi* was able to complete the life cycle in the two regions of Ashkezar and Ardakan in Yazd province in central Iran and produce acceptable dry and fresh biomass. Both of these areas are saline and arid regions, where the species presence, their growth and production in these areas indicated the high tolerance of salinity and drought. Therefore, *Alhagi* can be considered as an alternative forage plant for saline and arid rangelands. More research is needed to enhance our knowledge about quality of *Alhagi* forage in different phenological stages to feed different livestock.

REFERENCES

Amiri, B., Assareh, M.h., Jafari, M., Rasuli, B., and Jafari, A.A. (2012). Effect of NaCl & Na_2SO_4 on germination and seedling growth of Salicornia herbacea & *Alhagi persarum*. *Iranian journal of Range and Desert Research*, *19*, 233-243. https://doi.org/10.22092/ijrdr.2012.103154

Bazoubandi, M., Barati, M., and Sadrabadi, H.R. (2006). Physiological response of *Alhagi pseudoalhagi* to root exhausting management during fallow season. *Iranian Journal of Weed Science*, *2*, 84-95.

Bhardwaj, A.K., Kumar, R., Arora, S., and Singh, A.K. (2020). Sustainable natural resource management paradigms and research priorities in context to Indian agriculture. *Journal of Natural Resource Conservation and Management*, *1*, 1-6.

Browning, D.M., Snyder, K.A., and Herrick, J.E. (2019). Plant Phenology: Taking the Pulse of Rangelands. *Rangelands*, *41*, 129-134. https://doi.org/https://doi.org/10.1016/j.rala.2019.02.001

El Shaer, H.M. (2010). Halophytes and salt-tolerant plants as potential forage for ruminants in the Near East region. *Small Ruminant Research*, *91*, 3-12.

Enquist, C.A., Kellermann, J.L., Gerst, K.L., and Miller-Rushing, A.J. (2014). Phenology research for natural resource management in the United States. *International Journal of Biometeorology*, *58*, 579-589.

Hufkens, K., Keenan, T.F., Flanagan, L.B., Scott, R.L., Bernacchi, C.J., Joo, E., Brunsell, N.A., Verfaillie, J., and Richardson, A.D. (2016). Productivity of North American grasslands is increased under future climate scenarios despite rising aridity. *Nature Climate Change*, *6*, 710-714.

Jiang, H., Fang, L., Zhou, X., and Li, S. (2014). Improve alfalfa silage quality by adding *Alhagi sparsifolia* shap in initial bloom stage. *Transactions of the Chinese Society of Agricultural Engineering*, *30*, 328-335.

Jin, Q. (1994). *Alhagi sparsifolia* Schap.: A potentially utilizable forage in saline soils. In *Halophytes as a resource for livestock and for rehabilitation of degraded lands* (pp. 285-288). Springer.

Maraki, H., Sepehri, A., and Jafari, A. (2016, March 2-3, 2-16). *Investigation of phenology of Alhagi camelorum in Aq-Qala county of Golestan province* 2nd Conference on Conservation of Natural Resources and Environment, Ardabil, Iran.

Nikfam, F., Baghestani, M.A., Mirvakili, S.M., and Meighani, F. (2013). Investigating of phenological stages of camelthorn (*Alhaji pseudoalhagi* L.) in Yazd province. *Journal of Weed Ecology*, *1*, 1-8. https://www.sid.ir/en/Journal/ViewPaper.aspx?ID=419822

Pirasteh-Anosheh, H. (2020). Breaking seed dormancy of camelthorn (*Alhagi maurorum*) using different treatment and salinity tolerance threshold level evaluation at germination stage. *Iranian Journal of Seed Research*, *7*, 181-192. https://doi.org/10.29252/yujs.7.1.

Singh, Y., Mishra, V., and Singh, D. (2020). Optimizing seedlings number and spacing to harness productivity potential of salt tolerant rice cultivars in salt affected soils. *Journal of Natural Resource Conservation and Management*, *1*, 76-82.

Weber, D.J., and Hanks, J. (2006). Salt tolerant plants from the Great Basin region of the United States. In M.A. Khan and D.J. Weber (Eds.), *Ecophysiology of High Salinity Tolerant Plants* (pp. 69-106). Springer.

Zeng, J., Zeng, F., Arndt, S., Guo, H., Yan, H., Xing, W., and Liu, B. (2008). Growth, physiological characteristics and ion distribution of NaCl stressed *Alhagi sparsifolia* seedlings. *Chinese Science Bulletin*, *53*, 169-176.