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The role of phenological stages of *Hammada salicornica* on grazing management and sustainable utilization of rangeland forage

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Abstract

Hammada salicornica is a key range species in arid regions. In this study, phenological stages of *Hammada salicornica* were investigated at two desert vegetative regions of AbBarik Bam (Kerman province) and Tabas (Yazd province) during 2008-20111. In each vegetative region, after the registration of geographical features, 10 species of *Hammada salicornica* were selected and then phenological stages were recorded on special forms every 15 days and once a week during growing season and reproductive season, respectively. Results showed that, at AbBarik Bam, the vegetative growth of *H. salicornica* started from early March and continued in to late May. Due to the intense heat in July, the growth stopped and again in early October the growth continued upon receiving moisture. Flowering stage was in late November. The seeding stage started in early October and continued to the seed maturity stage in late October, and dry stage occurred in December. In Sarakhs region, vegetative growth started in early March and continued until mid-September. Flowering stage started in early October with the emergence of flowers and in the first decade of November seeding stage started and in the second decade of December seed maturity stage occurred, and finally drying stage started in the first decade of January. As a result, on the basis of phenological data of key rang species, determining the right time for livestock entry to and exit from rangelands and applying proper management in a rangeland grazing system as well as determining the best time for seed collection could be scheduled.

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Introduction

Geographical distribution of each plant species is controlled primarily by climatic factors. As a result, the distribution of each species is possible in certain areas. In addition to the absence or presence of a species, climatic conditions affect the phenological stages in a geographic area. Phenology refers to the study of biological phenomena and is considered one of the important issues in rangeland ecology. Rangelands of the country are of special importance in terms of economic, social and environmental issues and if they are managed and utilized properly they can play an important role in the economic prosperity of society. Management and proper utilization of rangelands require identifying and studying the phenology of key species. Phenology is considered as one of the extensive discussions of ecology especially in grazing management. Knowledge of phenological stages including vegetative growth, flowering, seeding and dormancy period are very important in grazing management, prevention of early grazing, knowing the palatability and nutritional value of plant species, and seed collection.

Hammada salicornica is one of the key species, widespread in arid regions, of which some phenological stages were investigated in this research. It is a perennial dicotyledonous plant species from Chenopodiaceae family. It has multiple, woody, and articulated stems with succulent leaves, originate from the soil surface. *Hammada salicornica* has a main root developed vertically in loose-structured soils. In terms of phenology, this species begins to grow in late winter when temperature and humidity requirements are provided. The flowering stage occurs in mid-October and the seeds reach physiological maturity until late December. This plant is wide spread in hot and arid regions of southern Iran, growing in the lower latitudes of 33° N. The average annual precipitation in vegetative regions of Iran varies between 60 to 300 mm. This plant is observed in different vegetation types of different regions as dominant or companion species together with many plant species from sea level to an altitude of 1800 meters above sea level. Considerable amounts of gypsum or lime is found in the chemical composition of the soil of *Hammada salicornica* habitats. It is regenerated by seeds in the nature and is mainly grazed by livestock in late growth. In general, *Hammada salicornica* is considered a suitable species for restoration of vegetation and soil stabilization in arid and desert regions.

One of the farmer's economic resources is rangeland's products which in terms of social and environmental issues are of utmost importance (Jafari *et al.,* 2004). Ehsani (2008) reported that the production of *Artemisia sieberi* was severely affected by climatic fluctuations. Rangeland is a complex ecological system affected by climatic factors, especially precipitation and temperature. Climate changes are very important in phenological stages including germination, vegetative growth, flowering, and seeding. Zarekia *et al.* (2012) studied the phenological stages of three range species including *Astragalus chaborasicus*, *Poa sinanica*, and *Stipa hohen-ackeriana* for two years by calculating Growth Degree Days in Khoshkeh Rood region of Saveh. Results showed that the start and end of phenological stages differed in two years but the GDD of two years were almost identical with a little difference. In other words, each phenological stage has an almost constant thermal need so that after receiving the required temperature, the emergence of stages is observed. Karlsson and Milberg (2007) defined the phenology as the study of growth dynamic, regulated mainly by environmental factors and it is measurable quantitatively. Researchers refer to the effective factors on the phenology of species. Hulme (2011) stated that the phenology of species is highly sensitive to climate and is a key indicator in environmental changes. Brando *et al.*, (2006) reported that temperature and photoperiod were the factors regulating the phenology.

Therefore, this research was aimed to investigate different phenological stages of *Hammada salicornica*as an important range species in desert vegetative

regions of the country to achieve a suitable range management and grazing system.

Materials and methods

Location and characteristics of the study areas

AbBarik Bam site is located between latitudes 28° 24' and 28° 34' N and longitudes 58° 23' and 58° 43' E in Kerman province. This site is limited to Loot Zangi Ahmad, Barez Mountain, Nesa watershed, and Kenar Naay watershed from North, South, West, and East, respectively. Maximum annual evaporation is 4035 mm and a temperature of about 50° C has been reported for this region. Tabas site is located 400 Km from north east of Yazd province between longitudes 56° 48' 47" and 56° 53' 53" and latitudes 33° 40' 41" and 33° 46' 28". Geographical and ecological characteristics of the study area are presented in Table 1.

Table 1. Geographical and ecological characteristics of the study area.

Row	Province	Site	Land Type	Climatic Region	Vegetative Region	Altitude (m)	Average Rainfall (mm)
1	Kerman	AbBarik	Plain	Desert	Central Iran	750	55
2	Yazd	Tabas	Plain	Desert	Central Iran	725	84

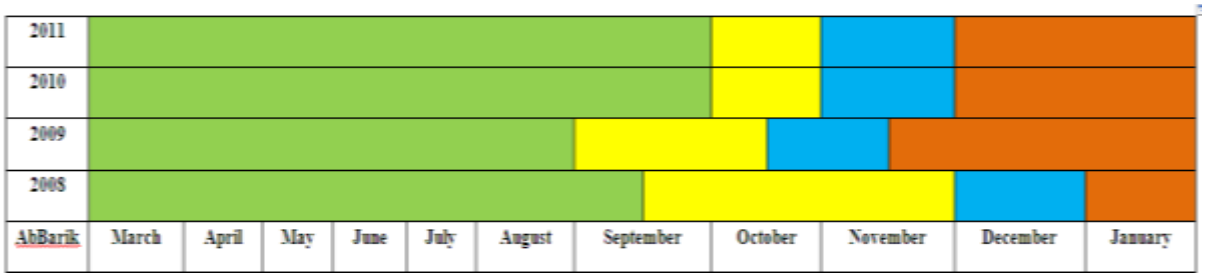

Fig. 1. Phenological stages of *Hammada salicornica* at AbBarik Bam site during 2008-2011.

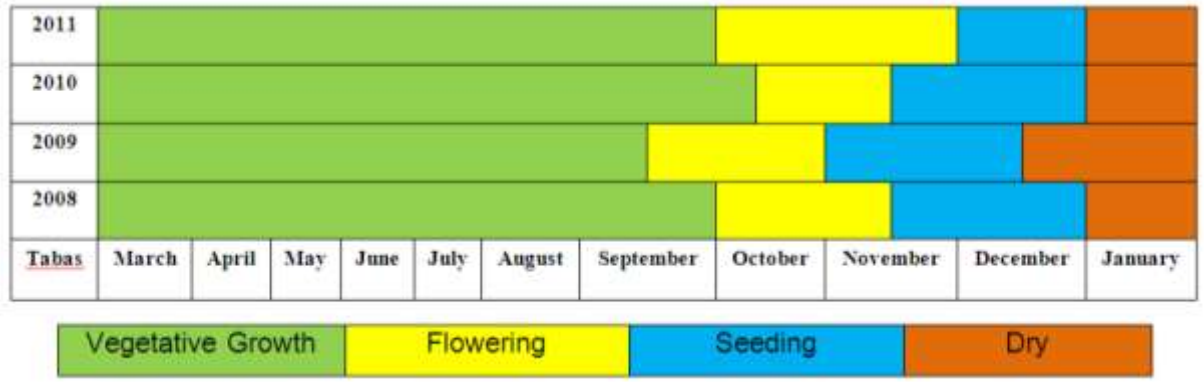

Fig. 2. Phenological stages of *Hammada salicornica* at Tabas site during 2008-2011.

Methodology

Phenological stages of *Hammada salicornica* were investigated in two vegetative regions of the country with different geographical locations during 2008-2011. In each vegetative region, after recording geographical characteristics, 10 bases were selected and during four years phenological stages including the start and end of vegetative growth, flowering, seeding and dormancy period were recorded every 15 days and once a week in growing season and reproductive season, respectively. Meteorological data including monthly average temperature and monthly precipitation were prepared from the nearest synoptic station and also drought period diagram was

drawn in order to be matched with different phenological stages. Ombrothermic curves of the studied stations were used to interpret climatic relationships and phenological stages.

Results

At AbBarik Bam site, minimum, maximum and average temperatures were recorded to be 41.25, 15.05, and 28.8°C. In all the years of the study, temperature and precipitation conditions were constant and only the amount of precipitation fluctuated. The rangelands of the study area are under utilization of rural and nomadic households. In this site, the vegetative growth stage of *Hammada salicornica* started from early March and continued until late June. Dormancy period started from July and again in early October vegetative growth continued upon receiving moisture. Flowering stage occurred in late November and the start of seeding to seed maturity stage was from early to late November and the plant became dry in December. According to the Ombrothermic curves of the site, the moisture resulting from regional rainfall had no long-term stability; thus it is not considered as a restriction in terms of soil compaction.

At Tabas site, maximum and minimum temperatures were recorded to be 50° and-9° C, respectively. The average evaporation was 3500 mm and the number of frost days per year was calculated to be 20 days. A plain and desert land type with a slope less than 5 percent and an alluvial soil are the characteristics of the study area.

The rangelands of this region are under utilization of rural households. In Sarakhs region, *Hammada salicornica*, after dormancy period with rising air temperature started the vegetative growth from early March. At the beginning of the vegetative growth stage, minimum and maximum air temperature was 8 and 16°C, respectively. Usually, its growth was slow until mid-May but vegetative growth became faster from late May with rising air temperature and continued until mid-September. This period took approximately 6 months. Repro-ductive growth stage with the emergence of flowers started in early October with decreasing air temperature and lasted for 30 to 35 days. Seeding stage including seed formation and seed maturity occurred in the first decade of November, and the second decade of November, respectively. Seed shedding usually occurs together with florets. Livestock movement in rangeland as well as wind leads to the shedding of florets and seeds easily. From the first decade of January, stems and leaves were withered and yellow and finally the species became dry.

Discussion

H. salicornica is a dominant plant species in AbBarik Bam site of Kerman province. It is a highly palatable species, which has been grazed by livestock. Vegetative growth of *H. salicornica* started with the emergence of buds in early March and continued until late June. Dormancy period started from July and again in early October vegetative growth continued upon receiving moisture.

Flowering stage occurred in late November and the start of seeding to seed maturity stage was from early to late November and the plant became dry in December. According to the results, the climatic conditions of the region had a main role on plant growth, leading to the changes in phenological stages of the species. Climatic changes and fluctuations prevailing in the region prevent the exact determination of the time for livestock entry to and exit from rangeland. According to the results obtained here, late March to early April and late July could be recommended as the best time for livestock entry to and exit from rangeland, respectively, which corresponds with the current grazing calendar in the region. *Hammada salicornica*, *Calligonum comosum*, and *Heliotropium ramosissimum* are the key species of the region, having maximum production.

In Sarakhs region, *Hammada salicornica*, after dormancy period and with rising air temperature started the vegetative growth from early March. At

the beginning of the vegetative growth stage, minimum and maximum air temperature was 8 and 16°C, respectively. Usually, its growth was slow until mid-May but vegetative growth became faster from late May with rising air temperature and continued until mid-September. This period took approximately 6 months. Reproductive growth stage started with the emergence of flowers in early October with decreasing air temperature and lasted for 30 to 35 days. Seeding stage including seed formation and seed maturity occurred in the first decade of November, and the second decade of November, respectively. Seed shedding usually occurs together with florets. Livestock movement in rangeland as well as wind leads to the shedding of florets and seeds easily. From the first decade of January, stems and leaves were withered and yellow and finally the species became dry.

Cornulaca monacanta, *Hammada salicornica*, and *Artemisia sieberi* are the key species of the region with maximum production. According to the results, mid-November to late December, when plant is in flowering and seeding stage, could be recommended as the best time for livestock entry to rangeland, having a one-month delay compared to the current grazing calendar in the region. This species is grazed by livestock during the grazing season in all phenological stages but grazing in spring and summer will cause to overgrazing, affecting the survival of plant species. Consequently, the best time for grazing is when plant is in seeding stage. Based on the traditional grazing calendar in the region, the time of livestock exit from rangeland is late January. At this time, there is almost no palatable forage in the rangeland. In the case of overgrazing, these species will be removed. According to the Fig.s, the majority of phenological stages occur in a shorter time period due to the drought condition and high temperature of the region. Phenological stages of *H. salicornica* starts about 1 or 2 weeks earlier and also is finished earlier in wet years. Accordingly, the period of rangeland grazing decreases about 1 to 2 weeks in droughts and vice versa, it increases in wet years.

Discussion

Generally, with regard to the start of vegetative growth in late March, the species has no problem in terms of soil moisture and if required temperature is provided, the vegetative growth of this species starts from the first decade of April and continues until October. It could be concluded that the start of vegetative growth in this species was highly affected by temperate. This finding corresponds with the results of other studies. Temperature has been introduced as the most influential factor on phenology compared to other climatic factors (Frank and Hofmann, 1989; Hulme, 2011; Keith, 2001). Tormoet defined phenology as the periodic study of plant and animal life cycles and how they are being affected by seasonal and annual variations in the climate Tormo *et al.* (2011). Fraser (2006) reported that the start of plant growth required a minimum temperature above zero. Lesica and Kittelson (2010) stated that phenological stages of plant species were affected by temperature and rainfall.

As a result, *H. salicornica* is an important plant species in arid and desert regions, widely distributed in these regions as dominant or companion species. On the other hand, *H. salicornica*is a drought tolerant species due to having deep roots and extraction of groundwater, producing substantial forage production which is grazed by light livestock (sheep and goats) in late autumn and winter as well as camel grazing throughout the year. Therefore, phenological data could be taken into consideration for proper grazing management, determining the best time for livestock entry to and exit from rangeland as well as the best time for seed collection towards restoration and range improvement to be applied by planners and range managers.

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