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Modeling phonological stages of *Artemisia sieberi* using GDD

Faranak Raoofi[*], Seyed Akbar Javadi

Department of Range Management, Science and Research Branch, Islamic Azad University, Tehran, Iran

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Abstract

Controlling the time when the livestock start to come in or go out of range and preventing them from early grazing is a key to effectively managing the ranges. Livestock grazing should be done when the plants are highly growing and producing. This study was conducted in a 4-year period during growing season to investigate the phonologic stages of *Artemisia sieberi* in four study areas.In each site 10 plants of *Artemisia sieberi* were marked and monitored once in seven days during vegetative growth and once in 15 days during reproductive stage to track the timing of phonology stages. The phonology stages included: vegetative stage, flowering, seed and dormant stage. Using temporal data, daily GDD (Growing Degree Days) were estimated in order to determine Accumulated Growing Degree Days (AGDD) for each phonology stage during three subsequent years, we added daily GDDs from the beginning of spring growth. Finally, we were able to present a model to predict the time when each phonology stage is about to happen in each site. To estimate model accuracy we used the recorded data in 2010. The results illustrated that calculating heat units or AGDD provided a more biologically accurate snapshot than time calendar. Although time calendar can be applied for some years, regarding to the early or late beginning of spring, it couldn't always coincide with the best time to start grazing. GDD is one of the indices most commonly used by horticulturists and agronomists to predict the suitability of a given area or the time of a particular growth stage of a plant.

[*] **Corresponding Author:** Faranak Raoofi ✉ Faranak.Raoofi@yahoo.com

Introduction

Rangelands account for about more than half of the land surface of Iran (Badripour *et al.,* 2006). The geographic extent and many important resourses of rangelands make their proper use and management vitally important to people everywhere. Artemisia sp is highly distributed in different parts of Iran like the other parts of the world. It is the dominant species of central plateau of Iran That is not only used for domestic livestock grazing but used for wildlife over the year as well. Grazing at the right time and for the right duration in a year is really prominent but most importantly, it is not clear and there will be a lot of fluctuations due to climate change every year. Hence, phonological studies can significantly contribute to the determination of this date (Moghadam, 2005). Shaykewich, 1994 stated: temperature, photoperiod and solar radiation are the effective factors on phonological stages. Many researchers Harrison,1994, Bertiller,1991, Keith,1996, Hunter,1992, Jordan,1989, Mohan,2010, Frank,1991 illustrated that among environmental factors, climatic ones especially temperature are highly affecting the growth and development of plants. Predicting growth phases using time calendar is difficult because temperature can vary greatly from year to year. Instead, using growing degree days (GDD) based on actual temperature is a simple and accurate way when a certain plant stage will occur (Perry Miller, Will Lanier and Stu Brandt , 2001). Wang (1960) reported that the duration of a particular stage of growth and development was directly related to temperature and using the sum of daily air temperature, this duration for particular species could be predicted. In recent studies, there have been a lot of models to depict the phonological reaction to temperature (Kramer *et al.,* 2000). Although there are different ways to make a model (Galan *et al.,* 1998; Hanninen, 1990, Maak and Von Storch, 1997), most of the models are based on temperature. In addition, temperature is a prime factor in agriculture and climatology models. GDD is a parameter that is used in most of growth analysis studies and can be applied in order to evaluate plant reaction to environmental condition (Russell MR *et al.,* 1984). Ansquer *et al.*,2009 studied Characterizing and predicting plant phenology in species-rich grasslands and concluded that the difference between average flowering time of plant communities was shown to be around 40 days. GDD has been widely used in relation to phonological events and maturity dates in crops like wheat (McMaster and Smika, 1988, Haider *et al.*, 2003). Vegetative and reproductive developmental stages of downy brome (*Bromus tectorum*) were predicted using growing degree days (Ball *et al.,* 2004). They supported the hypothesis that seed development can be related to cumulative GDD at a given geographic location. Plant phonology and growing degree days can be useful tools in tracking and predicting the annual timing of plant event and the accurate prediction of plant activity and life stage plays a crucial role in maintaining a successful grazing management program especially determining rangeland readiness. The main objectives of this study are: To investigate phonology stages of *Artemisia sieberi*. 2. To investigate how Artemisia sieberi is related to environmental factors. 3. To predict a model determining the relation between the plant and climate of the given area.

Materials and methods

Study sites

Four study sites were chosen including Dehno (Kerman), Nadooshan(Yazd), Khoshkrood(Save) and Tilabad(Golestan).

Sampling method

In this study, ten plants in each site were randomly chosen and marked. They were monitored once per seven days in vegetative growth stage and once per fifteen days in reproductive growth stage. Phonology stages that were tracked included: vegetative, flowering, seeding and end of growth.

All plants need to accumulate a certain amount of heat units to complete and reach different life stages in their development. Hence, temperature data were taken from the nearest weather station of a given site and for the sites that there was no meteorological station, temperature data from nearby stations were interpolated. To assess the accuracy of the result, using the weather data of nearby synoptic stations, the maximum and minimum temperature of one of the synoptic stations were made. To see whether the calculated values and the interpolated ones are matching, the data were analyzed using SPSS. The result showed that this method is highly accurate (RS=0/945).

Growing degree days or amount of energy required for a plant to reach each phonology stages, were calculated using a climate parameter named GDD (Alm *et al.* 1991) that is represented by the following equation:

GDD= (Tmax+Tmin)/2 – Tbase.

The basic concept is that development occurs when outdoor temperatures exceed a minimum level, or base temperature (Tbase). Base temperatures are determined experimentally. Tbase was considered 0 degrees in this study.

In each site, AGDD required for *Artemisia sieberi* to reach each phonology event for three consecutive years 2007, 2008, and 2009 based on timing of the beginning of each stage were calculated and in order for validation of the result, these data were compared with the data recorded by experts in 2010.

Results

Phonology

Results show that the temperature of a given region determines how fast the lifecycle takes; cooler=slower, while warmer=faster, the study species had a longer lifecycle (phonological stages) in wet seasons than dry seasons. Numbers of days taken to attain any phonological events varied in all the years and sites. The calendar method is based on past experience and the historical record and is an approximate date. As each spring is unique and the season starts and progresses differently from year to year and even in different areas, timing of each phonologic event is not the same in different years and different sites. In other word, plant activity and development is controlled by the temperature of surrounding environment. The plant need to get a certain amount of heat units to get each phonology stage.

Table 1. Date and amount of heat units required for *Artemisia sieberi* phonology stages in Khoshkrood.

year	Beginning of growth	Beginning of flowering		Full flowering		Seed stage		End of growth	
	date	date	AGDD	date	AGDD	date	AGDD	date	AGDD
2007	5.3.07	17.10.07	2085	20.11.07	2260	22.10.07	2263	27.12.07	2316
2008	5.3.08	30.9.08	2052	22.10.08	2226	22.10.08	2348	21.12.08	2399
2009	27.2.09	13.10.09	1960	21.11.09	1959	1.12.09	2177	10.01.2010	2341
2010	6.3.2010	29.9.2010	2039	26.11.2010	2272	16.11.2010	2373	12.12.2010	2430

Table 2. Date and amount of heat units required for *Artemisia sieberi* phonology stages in Bardsir.

year	Beginning of growth	Vegetative growth		Beginning of flowering		Full flowering		Seed stage		End of growth	
	date	date	AGDD	date	AGDD	date	AGDD	date	AGDD	date	AGDD
2007	5.3.07	22.3.07	129	27.9.07	3970	12.10.07	4175	24.11.07	4679	21.12.07	4836
2008	5.3.08	22.3.08	168	19.9.08	3967	4.10.08	4262	13.11.08	4812	17.12.08	4982
2009	5.3.09	21.3.09	183	7.10.09	3901	22.10.09	4208	22.11.09	4700	22.12.09	4859
2010	5.3.2010	19.3.2010	185	19.9.2010	3987	6.11.2010	4282	16.11.2010	4827	19.12.2010	4996

Growing degree days and phonology

The results of this study demonstrated that the amount of AGDD required for *Artemisia sieberi* to start flowering in Khoshkerood was 2085, 2052 and 1960 heat units from 2007 to 2009 that is highly matching the amount of AGDD in 2010 that was 2039 heat units (table1), the same goes with the other phonological stages while there is a significant difference among the date of per phonology event (table1). The accumulated GDD to reach flowering and seed stage varied in four sites. Artemisia in Dehno(table2) needed the highest amount of GDD to start flowering while the total GDD required for attaining seed stage ranged from 2177-2373 in Khoshkrood, the lowest amount, and 5515-5788 in Tilabad,the highest(table4). On average Artemisia took approximately the same amount of GDD to reach each phonology stage. However, these values were notably various for Artemisia to start a life event in different sites.

Table 3. Date and amount of heat units required for *Artemisia sieberi* phonology stages in Nadooshan.

year	Beginning of growth	Vegetative growth		Beginning of flowering		Full flowering		Seed stage		End of growth	
	date	date	AGDD	date	AGDD	date	AGDD	date	AGDD	date	AGDD
2007	5.3.07	4.4.07	183	23.6.07	1683	7.10.07	4006	16.11.07	4465	11.12.07	4603
2008	5.3.07	23.3.08	160	1.8.08	2864	2.10.08	4178	1.11.08	4606	29.10.08	4700
2009	29.3.09	10.3.09	167	15.6.09	1523	12.10.09	4003	11.11.09	4450	16.12.09	4630
2010	5.3.2010	18.3.2010	191	9.6.2010	1515	2.10.2010	4131	23.10.2010	4500	5.12.2010	4790

In this site (Tilabad) the calculated AGDD through different years was not significantly different, but it is considerable that in 2008 that was under drought stress, the amount of required AGDD is higher, compared to the other years. For other sites there is the same difference between wet and dry years. However, this difference is more remarkable in this site and no clear reason was found. (table4).

Table 4. Date and amount of heat units required for *Artemisia sieberi* phonology stages in Tilabad.

year	Beginning of growth	Beginning of flowering		Full flowering		Seed stage	
	date	date	AGDD	date	AGDD	date	AGDD
2007	29.3.07	5.6.07	1577	19.10.07	5304	3.11.07	5578
2008	20.2.08	28.5.08	1781	3.10.08	5384	22.10.08	5788
2009	5.3.09	17.6.09	1649	9.10.09	5100	27.11.09	5515
2010	5.3.2010	2.6.2010	1551	6.10.2010	5212	19.11.2010	5558

The figure compares the amounts of calculated AGDD in 2010 with those estimated during a long-term period for *Artemisia sieberi*. It is clear that GDD can consistently predict when a certain plant stage will occur. Having a reasonable estimate of plant phonology stage without actually visiting the field could save considerable time and expense.

Discussion

Artemisia sieberi started growing in the middle of second ten-days and beginning of third ten-days in four study sites. Because the mean temperature in March varied from 2007 to 2010, beginning of growing changed from 1 to 10 days. For example, Artemisia started growing earlier in 2008 than 2007 that can be due to increasing temperature and global warming. Also, mean temperature was higher in March 2008 than 2007. It is admittedly clear that numerous factors affect phonologic stages but many researchers (Thomson,1990, Hunter,1992...) mentioned that among climatic factors, temperature shows the most appreciable effect on plant growth and phonology events. In addition, temperature is a rational parameter in climatology and agriculture models. GDD is an index that is used in most of the studies of growth analysis and truly contributes to how to assess the plant reaction to environmental condition (Russell MR *et al.*, 1984).

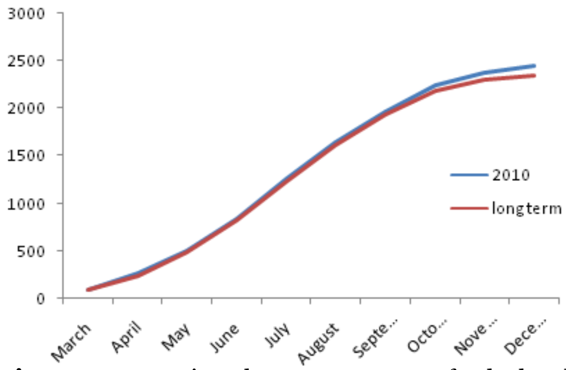

Fig. 1. A comparison between amount of calculated AGDD for a 4-year period and that for year 2010.

The results showed that, the date of beginning and end of growth was different over three consecutive years and these changes depend on temperature and soil moisture. For most of the plants, there must be enough accumulated heat units upper than base temperature to start phonologic stages. Base threshold vary with different species. *Artemisia sieberi* started growing when the minimum daily temperature reached oċ or more and oċ is often the best base temperature for predicting development in cool season plants.

Consequently, grazing management is frequently scheduled on a calendar-day basis. However, because of tremendous variations in the weather from location to location and year to year, calendar-based scheduling is greatly inaccurate. Plants bloom earlier during warm than cool seasons, since plant development is highly dependent on temperature. Using GDD can be a valuable tool for predicting plant phonology stages. Frank *et al.,* 1993 stated that although time calendar can be efficient for some years, using GDD is more accurate than using calendar dates, because each spring is unique and starts differently in each year and time calendar cannot be an appropriate way to determine the best time to start grazing. Frank *et al.,* in another study resulted that temperature is the most important weather factor that regulate plant growth and development and using AGDD is of great efficiency to find out range land readiness in perennial grasses. Nevertheless, during three study years, there weren't the same accumulated growing degree days for different phonology stages and there was a little difference that was probably for the way of making statistics. It was impossible to visit the sites for daily statistics in it was done once in two weeks, thus resulting in some variations to estimate heat units.

Our predicting model in this study was based on temperature. A lot of researchers have applied temperature to make predicting models so as to depict plants' phonologic responses. Although temperature is the most important factor affecting phonology stages, the other factors like water, sunlight as well as day length may have influence over it (Ghersa, 1995).

Finally, growing degree days are used to model the growth and development of plants during the growing season. Knowing.

Hat how many heat units are required for each plant life stage without visiting the field can save a lot of time and money. Also, this information helps growers to make better educated decisions on when to start grazing.

References

Akbarzadeh M, Mirhajy T. 2002. Investigate several important Rangeland species in Plour area. Research Institute of forests and rangelands, Proceedings of Range and Desert Research **7,** 140-121.

Alm, DM, McGiffen JRME , Hesketh JD. 1991. Weed phonology in Hodges, predicting Crop Phonology. Boca Raton, FL: USA CRC Press, 191-218.

Ansquer P, Al Haj Khaled R, Cruz P, Theau JP, Therond O, Duru M. 2009. Characterizing and predicting plant phonology in species-rich grasslands. Grass and Forage Science **64,** 57–70. http://dx.doi.org/10.1111/j.1365-2494.2008.00670.x

Badripour H, Eskandari N, Rezaee SA. 2006. Review of Rangeland of Iran. The organization of Forests, rangelands and watersheds, 110.

Bertiller Monica B, Beeskow Ana M, Coronato Fernando. 1991. seasonal environmental variation and plant phonology in arid Patagonia(Argentina). journal of Arid environment **21,** 1-11.

Ball Daniel A, Frost Sandra M, Gitelman Alix I. 2004. Predicting timing of downy brome (*Bromus tecturum)* seed production using growing degree days. Weed science **52,** 518-524.

Frank A.B. 1991. Morphological development of crested and western wheat grass flowering grazing. Agronomy Journal **38,** 826-828.

Frank AB, Ries RE . 1990. Effect of soil water, nitrogen and growing degree days on morphological development of crested and western grass. Journal of Range Manage **42(3),** 199-202.

Galan C, Fuillerat JM, Comtois P, Dominguez-Vilches E .1998. Bioclimatic factors affecting daily Cupressaceae flowering in southwest Spain. International Journal of Biometeorol **41,** 95–100.

Ghersa CM, Holt JS. 1995. using phenology prediction in weed management. a review, Weed Res **35,** 461-470.

Haider SA, Alam MF, Paul NK. 2003. Influence of different snowing dates on the phonology and accumulated heat units in wheat. Journal of Bioscience **3,** 932-939

Hanninen H. 1990. Modeling bud dormancy release in trees from cool and temperate regions, Acta Forestalia Fenn **231,** 47.

Harrison TJ. 2004. Regrowth of smooth Brome grass flowering defoliation, Cab. Journal Plant Science **74,** 531-537.

Hunter AF. 1992. Predicting the timing of budburst in temperate trees, Journal of Applied Ecology **29**, 597-604.

Jordan Gilbert L, Haferkamp Marshal R. 1989. Temperature responses and calculated heat units for germination of several range grasses and shrubs, Journal of Range Management **42,** 41-45.

Keith T. 2001. A method to incorporate phonology into land cover change analysis, Journal of Range Management, Vol. 54.

Kramer K, Leinonen I, Loustau D . 2000. The importance of phonology for the evaluation of impact of climate change on growth of boreal, temperate and Mediterranean forests ecosystem, an overview. International Journal of Biometeorol **44**, 67–75.

Maak K, Von Storch H. 1997. Statistical downscaling of monthly mean air temperature to the beginning of flowering of *Galanthus nivalis* L. in Northern Germany. International Journal of Biometeorol **41,** 5–12.

McMaster GS, Smika DE. 1988. Estimation and evaluation of winter wheat phonology in the centeral Great pains. Agric Forest meteorol **43**, 1-18.

Miller P, Lanier W, Brandt S. 2001. Using Growing Degree Days to Predict Plant Stages. Extention communications coordinator, communications services, Montana state university, Bozeman, MO, 1-8.

Moghaddam MR. 1998. Range and Range management. Tehran University Publication. 470p.

Mohan Singh , Bhatia HS. 2011. Thermal indices in relation to crop phonology and fruit yield of apple. University of Horticulture and Forestry, Seobag, Kullu, (HP), India. MAUSAM **63,** 449-454.

Russell MR, Wilhelm WW , Oison RA , Power JF. 1984. Growth analysis based on degree days. Crop Science **24,** 28-32.

Shaykewich CF. 1995. An appraisal of cereal crop phonology modeling. Canadian Journal of Plant Science **75,** 329-341.

Wang JY. 1960. A Critique of the heat unit approach to plant response studies. Ecology **41,** 785–790.