The Journal of Animal & Plant Sciences, 28(1): 2018, Page: 100-106
ISSN: 1018-7081

AIR TEMPERATURE EFFECT ON END OF FLOWERING OF *CIRSIUM ARVENSE* (L.) SCOP. IN A MOUNTAINOUS REGION OF GREECE

Aristidis Matsoukis*, Athanasios Kamoutsis and Aikaterini Chronopoulou-Sereli

School of Agricultural Production, Infrastructure and Environment, Agricultural University of Athens, Iera Odos 75, Athens 11855, Greece
*Corresponding author e-mail: armatsoukis@aua.gr

ABSTRACT

The quantitative determination of plant phenophases in mountainous warmer and colder regions is very useful information regarding evaluation of possible climatic variability and plant ecological success. No such information is available about one of the top weeds within agriculture, *Cirsium arvense* (L.) Scop. Thus, the impact of the average air temperature (T) of September and October on the onset (julian days) of the phenophase 'End of flowering' of *C. arvense* was studied at two areas of a mountainous region of Nafpaktia, Greece, Evinos River (823 m alt.) and Sarantena (1431 m alt.) for eight consecutive years (2007-2014). Sarantena was characterized as lower values of average T as compared to Evinos River. 'End of flowering' appeared later in Evinos River compared to Sarantena. The earliest and latest onset of 'End of flowering' took place in 2011 and 2012, respectively, for both examined areas. The 'End of flowering' onset correlated positively with the average T of October. The increase of 1 °C caused a delay of the onset of the examined phenophase by 8.49 and 5.70 julian days in Evinos River and Sarantena, respectively. The results of this study may contribute to planning of an effective control program of *C. arvense*.

Key words: air temperature; altitude; *Cirsium arvense* (L.) Scop.; End of flowering; mountainous Nafpaktia; phenology; river.

INTRODUCTION

Phenology, the study of the timing of periodic biological events (phenophases) in relation to calendar, provides valuable information for the plant development and yield potential which can be related with biotic or abiotic factors (Fageria 2007; Matloob *et al.* 2015). The environment and especially the air temperature (T), influences the phenophases in the animal and plant world (Shwhartz, 2003). Air temperature variability, from year to year, results in the fluctuation of the timing of plant phenophases (Chmielewski *et al.* 2004). Many studies in phenology have focused on the effect of increasing T on the timing or the duration of various plant phenophases (Menzel 2003; Chmielewski *et al*. 2004; Pellerin *et al.* 2012). Important phenophases of plant world, e.g. flowering, can be delayed or advanced depending on T (Jiménez *et al.* 2014). It has also been reported that flowering is influenced by elevation gradients (Ziello *et al.* 2009), a common characteristic of mountainous regions (MRs).

In these regions, generally, the topography in combination with the vegetation and atmospheric circulation systems result in the existence of a variety of microclimates (Barry, 2008). This variety is responsible, in a high degree, for the changes of the timing of plant phenophases (Ranjitkar *et al*. 2013), even in a relatively small area. In the cool areas and especially at the high altitudes of MRs, where T is decreased compared to low altitudes (Richardson *et al.* 2004), T variations play an important role on plant phenology (White and Howden 2010; Sahin *et al*. 2015). It has been reported that plants flower later as T decreases (Estiarte *et al.* 2011). So, at higher altitudes of MRs, flowering of plants delays in comparison with those growing in lower altitudes. Flowering and, in general, the phenophases of natural vegetation, are recommended as reliable ecological indicators of climatic evaluation (Chronopoulou-Sereli and Flocas 2010) and possible climate change.

In MRs of Europe and especially of Greece, one resistant representative plant species of the natural herbaceous vegetation, *Cirsium arvense* (L.) Scop. thrives in high populations. This plant species has special interest for agriculture, as one of the most serious invasive weeds (Skinner *et al.* 2000). No information is available, to our knowledge, with regard to the phenological behavior of *C. arvense* in MRs of Greece in relation to any environmental factor which may alter its ecological success. This information would be of great interest (Ziska, 2003), taking into account the importance of this plant within agriculture, as already mentioned. The need to conduct our present work derived from the test of the hypothesis of the different response of the start date of the phenophase 'End of flowering' of *C. arvense* to different T, resulted from different surroundings, in a mountainous region in Greece. Therefore, our study aims to make a first approach towards the aforementioned direction.

MATERIALS AND METHODS

Study region and measurement sites: Research was carried out in a MR of the municipality of Nafpaktia, Prefecture of Aitoloakarnania, western continental Greece, during the period September-October of eight successive years (2007-2014). Mountainous Nafpaktia is characterized by diverse relief and many brooks which flow into the Evinos River and these, along with the existence of *Quercus* sp. L. (oak), *Abies cephalonica* L. (fir), *Fagus silvatica* L. (beech), *Platanus* sp. L. (plane), and *Castanea sativa* Mill. (chestnut) trees which are interchanged, offer a unique beauty (Chalatsis, 2017) to the visitor who reaches the place for ecotourism and various recreational activities.

Two examined areas were selected, considering two main criteria, that is, the different altitude of each area from other and the abundant presence of the studied plant species, *C. arvense*, in both areas. The first study area comprised one measurement site (38°44′01.3″ N, 21°58′47.2″ E, alt. 1431 m) at the location Sarantena and the second study area two measurement sites, the first (Evinos 1) at a riverbank of Evinos River (38°43′22.5″ N, 22°00′59.6″ E, alt. 824 m) and the second (Evinos 2) at a riverbank of a tributary of Evinos (38°44′04.4″ N, 21°57′36.9″ E, alt. 821 m) at the location Mandrini (Figure 1).

Examined plant species and phenological data collection: *Cirsium arvense* is a robust, perennial plant (Moore, 1975), 90-150 cm in height, which appears pink (Altland, 2017) or red-pink flowers. This species thrives in uncultivated meadows of continental Greece (Kavvadas, 1956).To study the phenology of *C. arvense*, the phenophase 'End of flowering'was selected, where the petals in their majority fall or wither (Hess *et al.* 1997; Chronopoulou-Sereli and Flocas 2010). The selection of the aforementioned phenophase was based on its clear view.

In each study area, twenty healthy plants were selected randomly in a subarea with a maximum distance of 100 m around each measurement site, totally sixty plants. To estimate the start date of 'End of flowering' in each plant and study area, the relative phenological data were collected every five days (Chronopoulou-Sereli and Flocas 2010) for the whole studied period (1 September-30 October of 2007-2014). It is important to note that 'End of flowering' of *C. arvense* took place at September and October at the study region for the examined time period. The average start date was estimated as the mean value of the sum of start dates of 'End of flowering' of the selected individual plants in each study area and year.

Temperature data collection: To relate T data with the phenological data, T was recorded continually every min by sensors (SKH 2070, Skye Instruments Ltd, UK, accuracy ±0.2-0.5 °C) with data loggers (DL2, Delta-T Devices Ltd., UK) being placed in automatic meteorological stations (AMSs), each one in each measurement site. From these recorded initial data the average T was estimated for the months of September and October as well as the period September-October of each examined year, in which 'End of flowering' took place as mentioned before. The choice of the average T was based on its importance to express average thermal conditions, instead of maximum and minimum T which express instant thermal conditions (Matsoukis *et al.* 2008), leading thus to a more integrated view of the thermal environment in which 'End of flowering' appeared. About every five months, the sensors were tested in situ against reference sensors, where no shift errors were observed for any of the installed sensors. These were enclosed in appropriate shelters screened from precipitation and direct solar radiation and placed 1.5 m above ground surface.

Statistical analysis: At a first approach, analysis included Student's t-tests for the comparison of the start dates of 'End of flowering' of *C. arvense* between the examined subareas near the Evinos River, in each examined year. These tests extended to the average T of September and October, separately for each month. The results of the Student's t-tests did not reveal any significant difference [significance level (P)>0.05] regarding the aforementioned phenological data and T data. Note that the examined subareas near the Evinos River are similar, concerning their altitude, vegetation (Hatzigeorgiou, 2013) and average T of September and October. Therefore, we decided to present the aforementioned subareas as one study area (Evinos River), averaging their phenological data and T data.

After this arrangement, the experiment was carried out according to the two-factor completely randomized design. The first factor comprised two levels, each corresponding to each study area (Sarantena and Evinos River) and the second factor comprised eight levels, each corresponding to each study year (2007-2014), in which T data records and phenological estimations took place. For the phenological data, means (julian days) were calculated for each study area and year and used for analysis of variance (ANOVA). There were twenty one-plant replicates. The comparison of means, where appropriate, was made by Tukey's-HSD test (Roussos *et al.* 2009; Abdi and Williams 2010; Khalil *et al.* 2017).

Also, a linear correlation (Pearson's) analysis was conducted to detect possible relationships between start date of 'End of flowering' of the examined plant species and average T for both examined months (September and October) and September-October period. If a significant correlation was confirming (P≤0.05), a linear regression analysis (Jafarnejad *et al.* 2017) was carrying out to detect the possible response function of

'End of flowering' to average T. Where appropriate, regression lines were compared with each other. The statistics was performed using IBM SPSS Statistics 21 and MS Excel 2003 with results to be considered significant at $P \leq 0.05$.

RESULTS AND DISCUSSION

Sarantena was characterizing by lower values of average T in relation to Evinos River, by 1.4 °C to 3.4 °C and by 0.6 °C to 2.7 °C for September and October, respectively. The less favorable thermal conditions in Sarantena (lower average T), may be attributed partially to its higher altitude (Richardson *et al.* 2004) in relation to Evinos River. The maximum values of the average T of September and October, for both studied regions, were detected in 2011 and 2012, respectively (Fig. 2 & 3). From the ANOVA results it was clear that both area and time as well as their interaction affected the onset of 'End of flowering' of the examined plant species (Table 1).The examined phenophase appeared later in the area with the lower altitude (Evinos River) in comparison to Sarantena with differences being statistically significant in each examined year (Fig. 4). The maximum and minimum difference of the onset of 'End of flowering' between the two areas was 17.9 (2012) and 9.8 (2014) julian days, respectively.

Table 1. Analysis of variance for effects of time and area on the start date of 'End of flowering' of *Cirsium arvense* (L.) Scop. in the study region of mountainous Nafpaktia

	Start date (Julian days)		
	Df	Mean square	Variance ratio
Time	7	4938.51	205.94^{***}
Area	1	19188.41	800.16^{***}
Time × Area	7	79.69	3.32^{**}
Residual	304	23.98	

df: degrees of freedom.Time: Year (2007-2014). Area: Sarantena and Evinos River.
***, **: significance at $P \leq 0.001$ and $P \leq 0.01$, respectively.

When examining each study area individually, it was shown that the earliest onset of 'End of flowering' took place in 2011, September (269.2 and 252.4 julian days in Evinos River and Sarantena, respectively), which differed significantly from the other examined years in both areas (Figure 4). Although the highest average T of September was estimated in 2011 (18.7 °C and 16.5 °C in Evinos River and Sarantena, respectively), it was not sufficient to cause a delayed onset of 'End of flowering' in both studied areas. This fact could be justified by the lowest values of average T of October (9.7 °C and 7.0 °C in Evinos River and Sarantena, respectively), for the same year, which seem to be restrictive for the delayed appearance of 'End of flowering' in the aforementioned month. The start dates of the examined phenophase did not differ significantly among the years 2007, 2008 and 2009 in each study area. It seems that the differences of the average T of October, where the 'End of flowering' started, with maximum values of 0.5 °C and 1.0 °C in Evinos River and Sarantena areas, respectively, among the aforementioned years, had negligible impact on the start date of the aforementioned phenophase. Regarding its onset in 2010, it presented significant differences in comparison with the other studied years in both examined areas (except 2014 in Evinos River) while 2012 (where the latest appearance of 'End of flowering' took place), 2013 and 2014 differed from each other in the aforementioned region.

The delay of the appearance of 'End of flowering' in the Evinos River area (compared to Sarantena) may be explained by its more favorable thermal conditions, in all examined years, in relation to the higher altitude area (Sarantena). Similarly, the delayed onset of the aforementioned phenophase, in both study areas, for the years 2007, 2008, 2009, 2012 and 2013, (compared to 2010, 2011 and 2014) may be attributed to the more favorable thermal conditions of October in these years for each area.

To our surprise, the most delayed onset of 'End of flowering', in 2012, to Evinos River area (302.0 julian days), being attributed to the highest average T of October there (13.9 °C), may be related with an extended period of flowering or a bloom of *C. arvense* for a second time, the same year, in the region of the lower altitude. The hypothesis of the extended flowering period or the second bloom in Evinos River may be extended for the years 2007, 2008, 2009 and 2013, where the onset of 'End of flowering' appeared earlier than 2012 but not more than six julian days. It has been reported that plants may bloom for a second time the same year due to warm weather (Carpenter, 2011), and thus, it seems logical 'End of flowering' to delay. There are no comparable studies from literature on the effect of T on 'End of flowering' of the examined or other plant species. Therefore, further investigation is required to elucidate this topic.

The linear correlation analysis revealed that the start date of 'End of flowering' correlated significantly only with average T of October at both study areas (Table 2). This significant correlation may be explained by the fact that the start date of 'End of flowering' took place in October in the majority of the cases for each area. Also, the aforementioned correlation was positive, indicating that an increase of average T of October coincided with an increase of the number of julian days for the appearance of 'End of flowering', that is, a delay of this phenophase. It is clear, from the aforementioned analysis, that September did not have an impact on the onset of ‘End of flowering’ in the mountainous region of Nafpaktia, independently of altitude.

Table 2. Linear correlation coefficients for the average air temperature in relation to the average start date of ‘End of flowering’ of *Cirsium arvense* (L.) Scop. in the study region of mountainous Nafpaktia during the period 2007-2014.

	T_{Sep} (°C)	T_{Oct} (°C)	$T_{Sep-Oct}$ (°C)
		Evinos River	
Start date (Julian days)	-0.43	0.93**	0.57
		Sarantena	
Start date	-0.32	0.89**	0.53

T_{Sep}: Average air temperature of September. T_{Oct}: Average air temperature of October.
$T_{Sep-Oct}$: Average air temperature from September to October. **: Significance at $P \leq 0.01$.
Absence of asterisks indicates non-significance.

Table 3. Linear regression parameters for the average start date of ‘End of flowering’ of *Cirsium arvense* (L.) Scop. (y) in relation to average air temperature of October (x) in the study region of mountainous Nafpaktia during the period 2007-2014 [y = a + b(x)].

a	SE(a)	b	SE(b)	R^2
		Evinos River		
188.86***	15.98	8.49***	1.33	0.87
		Sarantena		
218.27***	11.77	5.70**	1.17	0.80

a: Y-axis intercept. SE(a): Standard error of a. b: Slope. SE(b): Standard error of b.
R^2: Coefficient of determination. ***, **: Significance at $P \leq 0.001$ and $P \leq 0.01$, respectively.

From the results of the linear regression of ‘End of flowering’ with the average T of October (Table 3), it was demonstrated that, for the given T values, an increase by 1 °C caused a delay of the onset of the aforementioned phenophase by 8.49 and 5.70 julian days in Evinos River and Sarantena, respectively. The comparison of the regression lines showed that the aforementioned slopes (8.49 and 5.70) were significantly different (t-test value: -4.77 at P=0.05) from each other. The impact of the T increase by 1 °C in the area with the lower altitude (Evinos River) on the start date of ‘End of flowering’ of *C. arvense* was greater, as the magnitude of the slope of the respective regression line was larger, in relation to the area with the higher altitude (Sarantena). To our knowledge, no literature is available regarding the estimation of ‘End of flowering’ based on T in cultivated and non-cultivated plants. Our study provides a first satisfactory approach of the estimation of onset of ‘End of flowering’ of *C. arvense* from T data, justified by the high coefficient of determination (R^2) value (>0.80) of an almost decade. Nevertheless, a greater number of years is required for a more precise estimation of the start date of ‘End of flowering’, based on T, for the examined plant species.

In conclusion, from the analysis of the study results, Evinos River area (altitude of approximately 823 m) showed higher average T values for September and October compared to Sarantena (altitude of 1431 m) in each year of the examined period of eight consecutive years (2007-2014). The aforementioned T values were greater by 1.4 °C to 3.4 °C and by 0.6 °C to 2.7 °C for September and October, respectively. The onset of ‘End of flowering’ of *C. arvense* appeared later in the warmer lower altitude area (Evinos River) compared to Sarantena in each studied year with the respective differences [maximum and minimum differences 17.9 (in 2012) and 9.8 (in 2014), respectively] being significant. ‘End of flowering’ appeared earlier in 2011 (269.2 and 252.4 julian days in Evinos River and Sarantena, respectively) and later in 2012 (302.0 and 284.1 julian days in Evinos River and Sarantena, respectively). The onset of ‘End of flowering’ in 2011 significantly differed from the respective onset in all the other examined years, for both areas. The ‘End of flowering’ onset exhibited a significant positive correlation with average T of October. The increase of 1 °C caused a delay of the onset of the aforementioned phenophase by 8.49 and 5.70 julian days in Evinos River and Sarantena, respectively. This delay differed significantly between the examined areas. Our study elucidates, for first time, to our knowledge, a part of the phenology of *C. arvense* (End of flowering) in a mountainous region. This knowledge may be useful for the control of this important invasive plant species within agriculture as well as for the evaluation of possible climatic variability in mountainous regions.

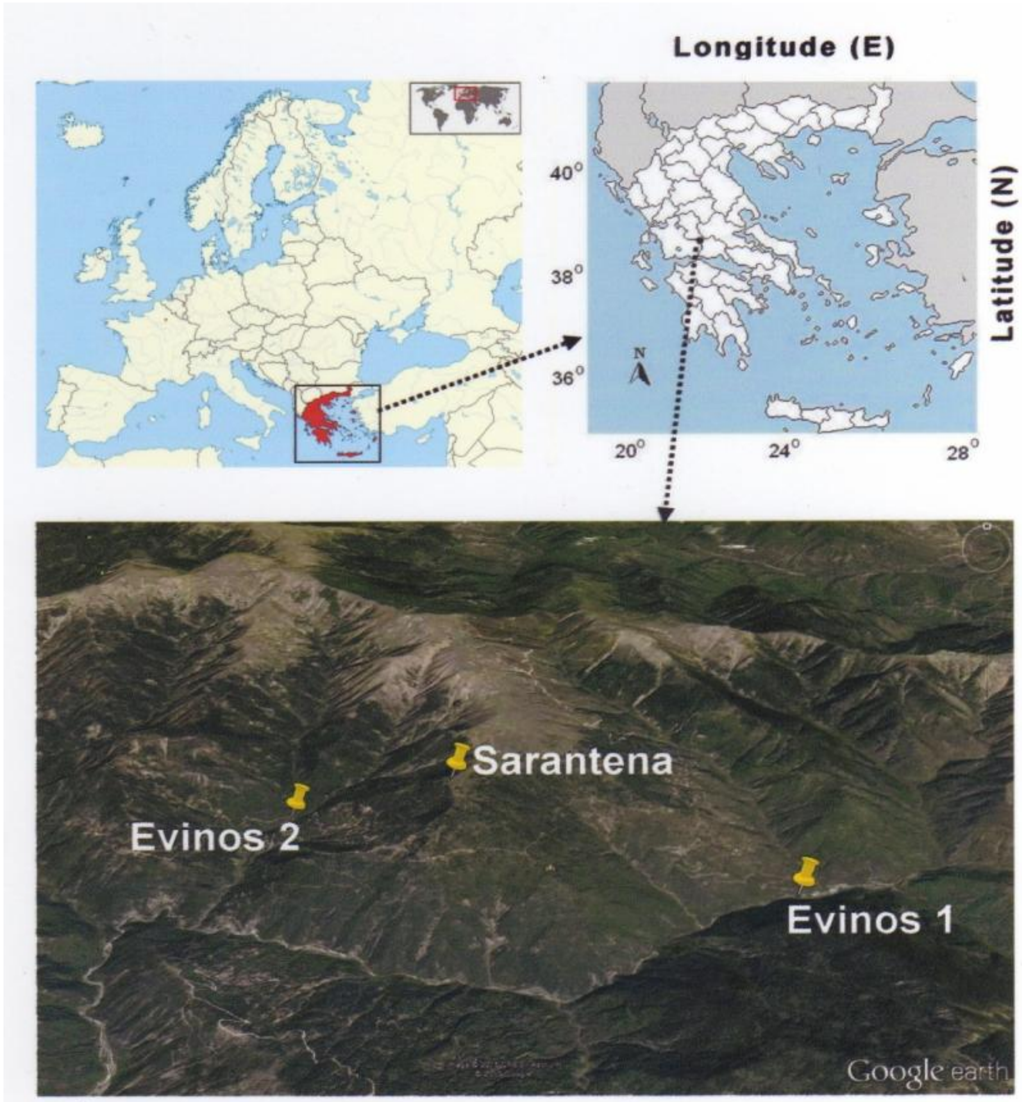

Figure 1. Study region of mountainous Nafpaktia and measurement sites.

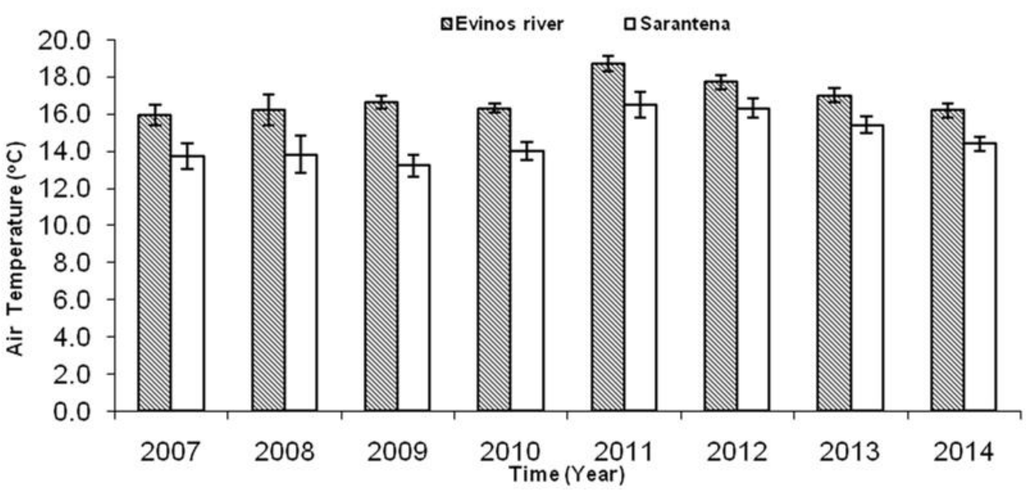

Figure 2. Average air temperature of September in the study region of mountainous Nafpaktia. In each column the bar on it represents the standard error of the mean (n=30).

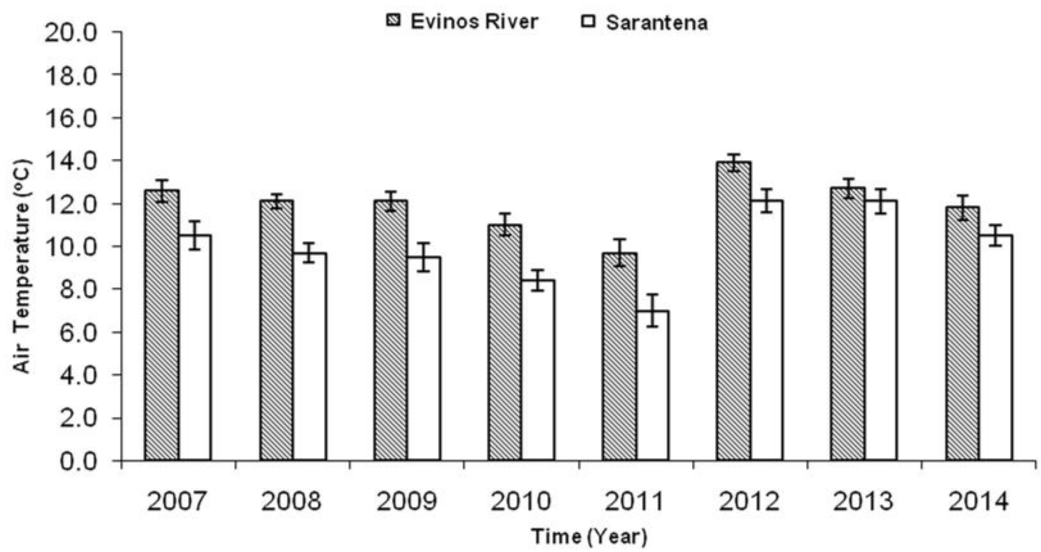

Figure 3. Average air temperature of October in the study region of mountainous Nafpaktia. In each column the bar on it represents the standard error of the mean (n=31).

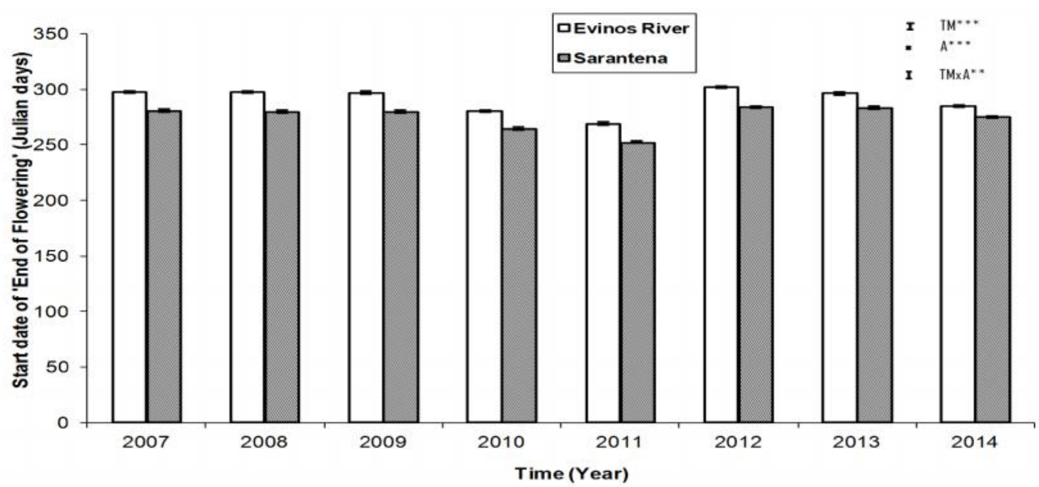

Figure 4. Effect of time (TM) and area (A) on the start date of 'End of flowering' of *Cirsium arvense* (L.) Scop. in the study region of mountainous Nafpaktia. In each column the bar on it represents the standard error of the mean (n=20). The vertical bars at the right represent the Tukey's HSD values at *P*=0.05 for the main effects of TM and A as well as their interaction (TMxA) (*, **: significant at *P*≤0.001 and *P*≤0.01, respectively).**

Acknowledgments: Thanks are due to Dr. P. Roussos (Associate Professor, Agricultural University of Athens) for his help regarding the completion of the last graph.

REFERENCES

Abdi, H. and L.J. Williams (2010). Tukey's honestly significant difference (hsd) test. In: Encyclopedia of Research Design Volume 3 (Salkind N., ed.). Sage Publications, Inc., Thousand Oaks, California, (USA), pp. 583-585.

Altland, J. (2017). *Cirsium arvense* – Canada thistle. Oregon State University, North Willamette Research & Extension Center, Aurora (USA). <http://oregonstate.edu/dept/nursery-weeds/feature_articles/thistles/thistles.html>. Accessed 2017 Nov 22.

Barry, R.G. (2008). Mountain Weather and Climate. 3rd Ed. Cambridge University Press; New York (USA). 532 p.

Carpenter, J. (2011). Flowers bloom for a second time this year, Science & Environment, BBC, London (UK). <http://www.bbc.com/news/science-

environment-15107243>. Accessed 2017 Nov 22.

Chalatsis, J. (2017). Mountainous Nafpaktia, Municipality of Nafpaktia (Greece). <http://www.nafpaktos.gr>. Accessed 2017 Nov 22.

Chmielewski, F. M., A. Müller and E. Bruns (2004). Climate changes and trends in phenology of fruit trees and field crops in Germany, 1961-2000. Agric. For. Meteorol. 121(1-2): 69-78.

Chronopoulou-Sereli, A. and A. Flocas (2010). Lessons of Agricultural Meteorology and Climatology. Ziti Publications; Thessaloniki (Greece). 573 p.

Estiarte M., G. Puig and J. Peñuelas (2011). Large delay in flowering in continental versus coastal populations of a Mediterranean shrub, *Globularia alypum*. Int. J. Biometeorol. 55(6): 855-865.

Fageria, N. K. (2007). Yield physiology of rice. J. Plant Nutr. 30(6): 843-879.

Hatzigeorgiou, M. E. (2013). Microclimatic conditions of the mountain formation of Oxia (Prefecture of Aitoloakarnania). Postgraduate diplomatic dissertation. Agri. Univ. of Athens, Athens, Greece. 138 p.

Hess, M., G. Barralis, H. Bleiholder, L. Buhr, T. Eggers, H. Hack and R. Stauss (1997). Use of the extended BBCH scale general for the descriptions of the growth stages of mono and dicotyledonous weed species. Weed Res. 37(6): 433-441.

Jafarnejad, A., M. A. Kamali, S. J. Fatemi and M. Aminafshar (2017). Genetic evaluation of laying traits in Iranian indigenous hens using univariate and bivariate animal models. The J. Anim. Plant Sci. 27(1): 20-27.

Jiménez, M. A., M. A. Cedrà and J. Rita (2014). The effect of the ambient conditions on the life cycle of a bulbous plant. Tethys 11: 39-49.

Kavvadas, D. (1956). Illustrative Botanical Plant Lexicon, Volume D΄. National and Kapodistrian Univ. of Athens, Athens, Greece. 510 p.

Khalil, A. A., M. R. Khan, M. A. Shabbir and K. U. Rahman (2017). Comparison of antioxidative potential and punicalagin content of pomegranate peels. The J. Anim. Plant Sci. 27(2): 522-527.

Matloob, A., A. Khaliq, A. Tanveer, F. Rasul and A. Wahid (2015). Thermal time accumulation and heat use efficiency of direct seeded fine aromatic rice. The J. Anim. Plant Sci. 25(3): 755-762.

Matsoukis A., A. Kamoutsis and A. Chronopoulou-Sereli (2008). Meteorological conditions and growth of lantana (*Lantana camara* L.) after treatments with 'onium-type' growth regulators. Proc. 8^{th} Conference on Meteorology-Climatology-Atmospheric Physics Volume A. (Chronopoulou-Sereli A., ed.), GDI Studio, Piraeus (Greece), pp. 370-376.

Menzel, A. (2003). Plant phenological anomalies in Germany and their relation to air temperature and NAO. Clim. Change 57(3): 243-263.

Moore, R.J. (1975). The biology of Canadian weeds: 13. *Cirsium arvense* (L.) Scop. Can. J. Plant Sci. 55(4): 1033-1048.

Pellerin, M., A. Dellestrade, G. Mathieu, O. Rigault and N. Yoccoz (2012). Spring tree phenology in the Alps: effects of air temperature, altitude and local topography. Eur. J. Forest Res. 131: 1957-1965.

Ranjitkar, S., E. Luedeling, K.K. Srethsha, K. Guan and J. Xu (2013). Flowering phenology of tree rhododendron along an elevation grandient in two sites in Eastern Himalayas. Int. J. Biometeorol. 57(2): 225-240.

Richardson, A.D., X. Lee and A.J. Friedland (2004). Microclimatology of treeline spruce-fir forests in mountains of the northeastern United States. Agric. For. Meteorol. 125(1-2): 53-66.

Roussos P., N. K. Denaxa and T. Damvakaris (2009). Strawberry fruit quality attributes after application of plant growth stimulating compounds. Sci. Hortic. 119(2): 138-146.

Sahin, U., Y. Kuslu and F. M. Kiziloglu (2015). Response of cucumbers to different irrigation regimes applied through drip-irrigation system. The J. Anim. Plant Sci. 25(1): 198-205.

Shwhartz, M. D. (2003). Introduction. In: Phenology: An integrative environmental science. (Schwartz M.D., ed.). Kluwer Academic Publishers, Dordrecht (Netherlands), pp. 3-7.

Skinner, K., L. Smith and P. Rice (2000). Using noxious weed lists to prioritize targets for developing weed management strategies. Weed Sci. 48(5): 640-644.

White, D.H. and S.M. Howden (2010). Climate and its effects on crop productivity and management. In: Soils, Plant Growth and Crop Production Volume I. (Verheye W.H., ed.). EOLSS Publishers Co Ltd, Paris (France), pp. 44-78.

Ziello, C., N. Estrella, M. Kostova, E. Koch and A. Menzel (2009). Influence of altitude on phenology of selected plant species in the Alpine region (1971-2000). Clim. Res. 39(3): 227-234.

Ziska, L. H. (2003). The impact of nitrogen supply on the potential response of a noxious invasive weed, Canada thistle (*Cirsium arvense*) to recent increases in atmospheric carbon dioxide. Physiol. Plant. 119(1): 105-112.