P1.2 RESPONSE OF SOME PHENOLOGICAL GARDEN SPECIES TO INTER-ANNUAL WEATHER VARIABILITY

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1. INTRODUCTION

The annual timing of spring phenological events is mainly driven by temperature after the dormancy is overcome. Variations in phenological stages are therefore a valuable source of information for investigating the possible impact of climate variability and change on plant species (Chmielewsky and Rötzer 2002). Recent studies indicating changes in phenological stages in plant and animal species provide evidence that ecosystems are responding to climate change (Menzel 2000; Wolfe et al. 2005). However, informations are still scarce for Mediterranean and semi-arid ecosystems (Penuelas et al. 2002).

This study shows the phenological behaviors of some Mediterranean and higher latitude species planted in two phenological gardens located at different latitude in Italy. The paper also attempts to investigate the variability in phenophase occurrence between 1986 and 2005.

2. MATERIALS AND METHODS

The sites are located in Oristano, Sardinia, Italy (39° 53' N, 8° 37' E, 11 m above sea level) and S. Pietro Capofiume, Emilia Romagna, Italy (44° 39' N, 11° 37' E, 10 m above sea level).

In the phenological garden of Oristano, the soil is alluvial, sub–alkaline, sand predominates in the first 0.3-m layer while sand–clay in the 0.3–0.6-m layer. The mean annual rainfall is about 581 mm with a large water deficit from May to September. The average annual air temperature is about 17 °C. Mean maximum and minimum air temperatures are moderated because of the short distance from the sea. Also, the winter season can be dry and winter temperature is not low enough to cause vegetation break. Prevailing wind directions are from the sea (West) and land (East).

In the phenological garden of San Pietro Capofiume soil is clay-lime, with basic pH. Climate is near-continental under the low influence of the Adriatic sea mitigation. The area is often foggy with thermal inversion during winter and early spring. Summer is hot and humid. Mean annual rainfalls are about 600 mm with two rainy periods in April and October.

Both gardens were set up in the early eighties following the directives of the International Phenological Gardens in Europe (IPG). Phenological observations were taken on Mediterranean forest species and shrubs in Sardinia, and on several forest species typical of higher latitude in Emilia Romagna using the BBCH scale system (Meier, 1997): *Pistacia lentiscus*, *Olea europea*, *Myrtus communis*, *Quercus ilex*, *Spartium junceum*, *Robinia pseudoacacia*, *Cercis siliquastrum*, *Salix chrysocoma*, *Tilia cordata*, *Populus tremula*, *Celtis australis* in Oristano and *Salix smithiana*, *Salix viminalis*, *Ligustrum vulgare*, *Corylus avellana*, *Cornus mas*, *Cornus sanguinea*, *Quercus robur*, *Fagus sylvatica*, *Laburnum anagyroides*, *Crataegus monogyna*, *Prunus psinosa*, *Prunus avium*, *Spartium junceum* in S.Pietro Capofiume.

Air temperature and other meteorological variables were recorded from a weather station located in the phenological Gardens sites. Maximum and minimum air temperature values were used to calculate cumulative degree-days (CDD) from 1 January using a temperature threshold of 0 °C. The CDD were calculated using the Temperature Model (Cesaraccio et al. 2001) that uses daily maximum and minimum air temperature values to produce a hourly temperature and then calculates the CDD on a daily base. The use of hourly air temperatures values for calculating CDD gives good accuracy and an acceptable error level.

Data analysis was conducted to describe the phenological behaviour of native and non-native species, and to assess their sensitivity to weather variability.

3. RESULTS AND DISCUSSION

To investigate the inter-annual variability in the beginning of growing season and flowering phases in Italy, phenological data-sets from two sites of the Italian Phenological Garden network were analyzed.

Mean phenological and extreme dates for some of the species located in the two Gardens are reported in Tables 1 and 2. The mean dates of bud-burst occurred between 15 March and 23 April in Oristano, with a greater range for the non-native species (*Cercis siliquastrum* and *Salix chrysocoma*), and between 24 March and 11 April in S.Pietro Capofiume, with a greater range for *Spartium*. Flowering stage dates were, on average, from 4 days (*Cercis siliquastrum*) to 61 days (*Myrtus communis*) after bud-burst. Again, *Salix chrysocoma* showed the widest range in date occurrence (about a 3 month span of dates) and *Robinia pseudoacacia* the lowest range (23 days) in Oristano. Flowering stage dates occurred after 13

(*Prunus avium*) to 55 (*Tilia cordata*) days in S.Pietro Capofiume.

Table 1. Mean phenological stage dates and extreme dates of the studied species in Oristano (n = number of recorded years).

	n	Mean Date	Earliest	Latest
Bud Break				
Salix chrysocoma (Willow)	14	15 Mar	23 Feb (1989)	10 May (1996)
Robinia pseudoacacia (False Acacia)	17	01 Apr	17 Mar (2002)	22 Apr (1993)
Cercis siliquastrum (Judas Tree)	16	04 Apr	02 Mar (1989)	20 Jun (1991)
Olea europea (Olive)	11	05 Apr	15 Mar (1996)	22 Apr (1993)
Spartium junceum (Spanish Broom)	6	06 Apr	23 Mar (1994)	22 Apr (1993)
Pistacia lentiscus (Lentisc)	11	10 Apr	14 Mar (1995)	10 May (1996)
Tilia cordata (Lime)	16	10 Apr	27 Mar (1997-98)	21 Apr (2005)
Myrtus communis (Myrtle)	15	23 Apr	30 Mar (1994)	10 Jun (1987)
Quercus ilex (Holm oak)	11	23 Apr	9 Apr (2005)	20 May (1995)
Flowering				
Salix chrysocoma	11	02 Apr	06 Mar (1989)	01 Jun (1996)
Cercis siliquastrum	15	08 Apr	26 Mar (1990)	29 Apr (2005)
Pistacia lentiscus	14	17 Apr	28 Mar (1990)	04 May (1994)
Spartium junceum	5	27 Apr	13 Apr (1994)	21 May (1992)
Robinia pseudoacacia	11	29 Apr	17 Apr (1989)	09 May (1992)
Olea europea	6	08 May	20 Apr (1991)	20 May (1993)
Quercus ilex	6	14 May	27 Apr (1991)	20 May (1993)
Tilia cordata	8	23 May	16 Apr (1996)	15 Jun (1990)
Myrtus communis	10	22 Jun	07 Jun (1995)	07 Jul (1987)

Table 2. Mean phenological stage dates and extreme dates of the studied species in S.Pietro Capofiume (n = number of recorded years).

	n	Mean Date	Earliest	Latest
Bud Break				
Prunus Avium	12	24 Mar	10 Mar (2005)	06 Apr (1996)
Robinia pseudoacacia (False Acacia)	12	12 Apr	28 Mar (1997)	24 Apr (1998)
Spartium junceum (Spanish Broom)	12	05 Apr	17 Mar (2005)	23 Apr (1996)
Tilia cordata (Lime)	12	11 Apr	01 Apr (2004)	18 Apr (1996)
Flowering				
Prunus Avium	12	06 Apr	22 Mar (2002)	21 Apr (2005)
Robinia pseudoacacia	12	07 May	22 Apr (2004)	26 May (1995)
Spartium junceum	12	13 May	22 Apr (2004)	28 May (1995)
Tilia cordata	12	05 Jun	20 May (2004)	16 Jun (1995)

In Table 3, cumulative degree day (CDD) values, and predicted and observed flowering dates for some species of the Oristano garden for two observation periods (1986-1996 and 1997-2005) are reported. The number of CDD varies between species and increases from 1986-1996 period to 1997-2005 period. In general, earlier flowering dates were observed for non-Mediterranean species, except for *Quercus ilex*, which showed 13 days advance. Comparison of CDD values and flowering dates for *Robinia* and *Tilia* in the two sites showed that blooming occurred in S.Pietro Capofiume, where heat accumulation was lower, on average 15 and 16 days later respectively than in Oristano (Table 4). In addition, the predicted flowering date was estimated using the CDD model. To test the accuracy of the CDD in predicting, RMSE between predicted and observed flowering dates was calculated. The RMSE values vary largely with species in both sites.

Table 3. Predicted and observed flowering date occurrence and cumulative degree day (CDD) values from 1 January for Oristano species. Mean, standard deviation (σ), coefficient of variation (CV), and root mean square error (RMSE) are reported.

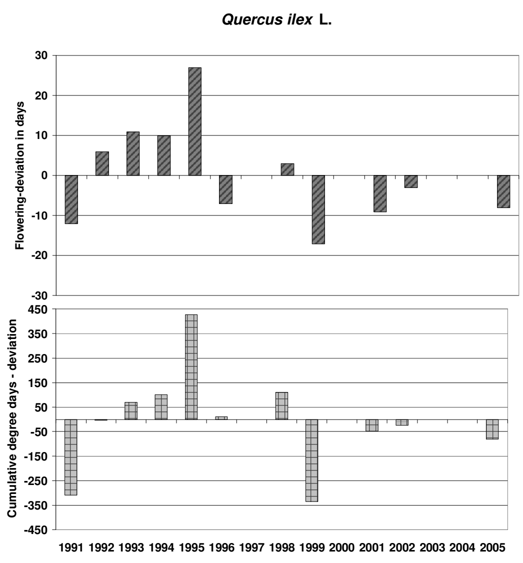
Species		Pred (doy)	Obs (doy)	CDD	Pred (doy)	Obs (doy)	CDD
		1986-1996			1997-2005		
Cercis	**mean**	100	98	1001	94	100	1023
	σ	8	9	152	6	12	90
	CV(%)	8	9	15	7	12	9
	RMSE	11			6		
Tilia	**mean**	147	143	1705	141	140	1859
	σ	6	24	417	8	16	242
	CV(%)	4	16	24	6	12	13
	RMSE	21			11		
Robinia	**mean**	122	120	1284	112	112	1302
	σ	8	8	125	9	4	162
	CV(%)	7	6	10	8	4	12
	RMSE	8			8		
Species		**Pred (doy)**	**Obs (doy)**	**CDD**	**Pred (doy)**	**Obs (doy)**	**CDD**
		1986-1996			1997-2005		
Myrtus	**mean**	171	168	2177	163	167	2310
	σ	9	6	168	8	9	265
	CV(%)	5	4	8	5	6	11
	RMSE	8			10		
Pistacia	**mean**	112	108	1156	107	109	1267
	σ	6	12	204	6	7	115
	CV(%)	6	11	18	5	7	9
	RMSE	15			10		
Olea	**mean**	135	129	1438	128	129	1603
	σ	7	10	216	3	15	255
	CV(%)	5	8	15	2	12	16
	RMSE	16			13		
Quercus	**mean**	134	135	1540	127	122	1416
	σ	7	14	236	3	7	187
	CV(%)	5	10	15	3	6	13
	RMSE	14			10		

Table 4. Predicted and observed flowering date occurrence and cumulative degree day (CDD) values from 1 January for S.Pietro Capofiume species. Mean, standard deviation (σ), coefficient of variation (CV), and root mean square error (RMSE) are reported.

Species		**Pred (doy)**	**Obs (doy)**	**CDD**
			1994-2005	
Prunus	**mean**	97	96	568
	σ	10	10	108
	CV(%)	11	11	19
	RMSE	10		
Robinia	**mean**	128	127	986
	σ	4	10	202
	CV(%)	2	8	21
	RMSE	8		
Tilia	**mean**	156	156	1501
	σ	4	9	170
	CV(%)	2	6	11
	RMSE	8		
Spartium	**mean**	134	133	1086
	σ	5	12	233
	CV(%)	3	9	21
	RMSE	12		

The changes in the average flowering dates in both gardens correspond well with the deviation of the mean CDD values as shown for *Quercus* and *Tilia* (Figures 1 and 2) in Oristano, and for *Tilia* and *Spartium* (Figures 3 and 4) in S.Pietro Capofiume.

Figure 1. Deviation of the average flowering date (days) and the mean cumulative degree-day for *Quercus* (1986-2005) at Oristano site.



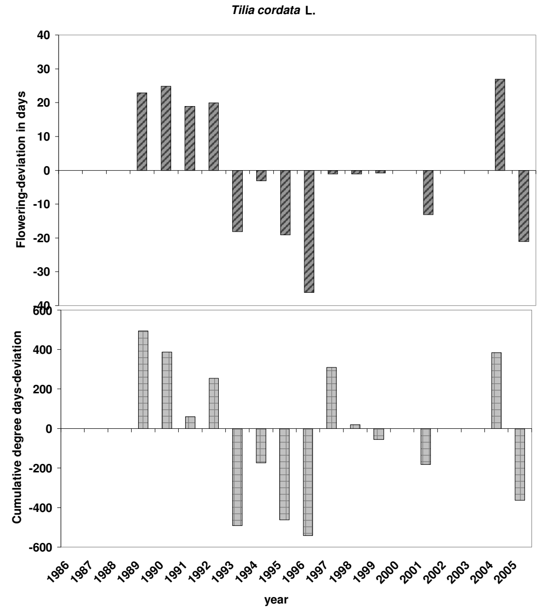


Figure 2. Deviation of the average flowering date (days) and the mean cumulative degree-day for *Tilia* (1986-2005) at Oristano site.

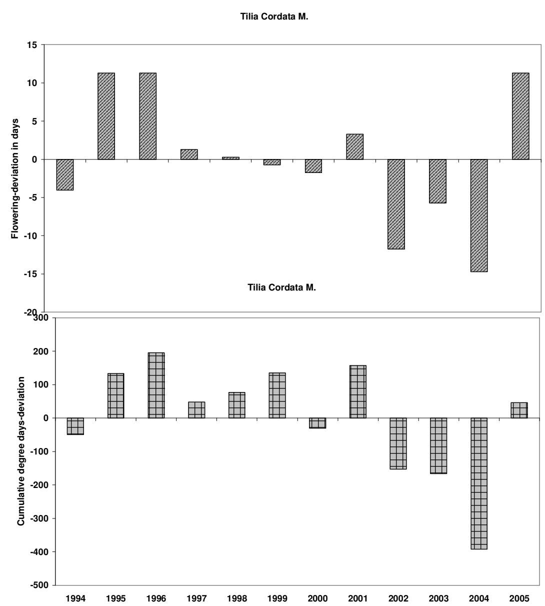


Figure 2. Deviation of the average flowering date (days) and the mean cumulative degree-day for *Tilia* (1994-2005) at S.Pietro Capofiume site.

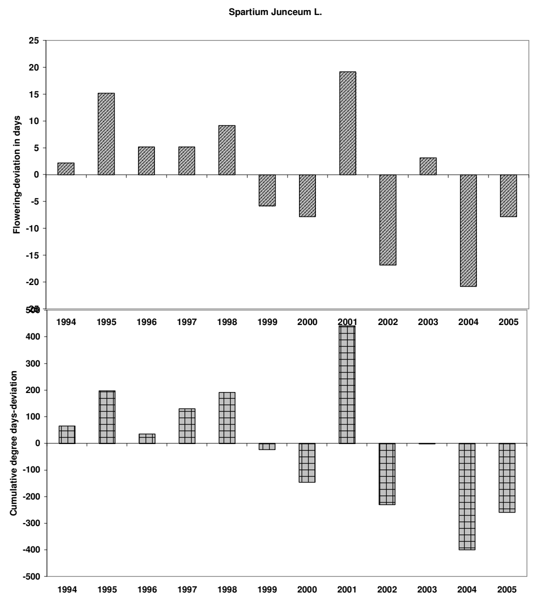


Figure 2. Deviation of the average flowering date (days) and the mean cumulative degree-day for *Spartium* (1994-2005) at S.Pietro Capofiume site.

4. CONCLUSIONS

The increase in mean CDD in the last decades led to an earlier flowering dates in Oristano for non-native species. There were non significant differences in flowering dates occurrence for Mediterranean species. The results from the two sites showed that there is a good correspondence between changes in mean CDD values and mean flowering dates.

5. REFERENCES

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