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The use of phenoclimatic models to characterize environments for chilling and heat requirements of deciduous fruit trees: methodological approaches and initial results

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Abstract: The findings of a climatological study designed to determine environmental potential in meeting the chilling and heat requirements of deciduous fruit trees in Sicily are reported and discussed. Three phenoclimatic models (chilling hour accumulation and the Utah and North Carolina models) were applied to three years of hourly thermograph records from eleven environments and evaluated. Data for the initial day of chilling accumulation and the date of rest completion, as well as the dynamics of chilling and heat accumulation, are included. Of the two methods employed for estimating hourly temperature from maximum and minimum readings (linear and sine-logarithmic interpolations) the latter showed the best fit. Principal component analysis (PCA) of the phenoclimatic variables resulted in at least two main types of environmental patterns that meet chilling and heat demands, albeit the analysis revealed a marked variation between years. While data analysis for subsequent years is continuing, this initial survey has proved to be valuable in defining complex land suitability models and local ecological limits to deciduous fruit tree cultivation.

1. Introduction

In the course of their annual biological cycle temperate-zone deciduous fruit trees alternate active growth with a period of inactivity or rest, during which a temporary suspension of visible growth occurs (Samish, 1954). The conditions the plant must regularly meet to break the rest phase are provided by specific chilling requirements, generally termed winter chilling requirement (WCR), which vary according to species and cultivar. Once the WCR has been satisfied, and not all low temperatures have the same efficacy in fulfilling it, the onset of bud-break and subsequent development up to bloom are linked to growth-inductive temperatures.

As with low temperature, not all high temperatures have the same efficacy in meeting the heat requirement (HR) for plant development. Weinberger (1950), working with peach trees, suggested that 7.2°C was the threshold temperature for maximum effectiveness and devised an index to calculate chilling based on the accumulation of hours below 7.2°C, which he termed 'chilling hours' (CH). Subsequently, Erez and Lavee (1971) reported that temperatures above 7.2°C had some influence on breaking rest and suggested the use of 'weighted chill hours' so as to account for the effect of temperatures above and below the optimum 6°C. They also included the antagonism exerted by the alternation of high (>21°C) and low temperatures in daily cycles.

Richardson *et al.,* (1974), working form previous reports and personal verification, devised a model to evaluate chilling action that is based on the daily accumulation of 'chill units' (CUs), where 1 CU is one hour of exposure at the optimum 6°C. Better known as the 'Utah model', it is premised on the fact that as temperatures diverge from the optimum their relative effectiveness diminishes. The same authors also developed a rapid method to calculate CUs via the daily maximum and minimum temperatures, which are more easily determined than the hourly temperature used initially. Subsequently, by combining their CU model with estimated heat accumulation, termed 'growing degree hours' (GDHs), which starts from the date of completion of rest, they constructed a phenoclimatic prediction model for peach bud development (Richardson *et al.,* 1975), which was later replaced by the more accurate 'Asymcur' model (Anderson *et al.,* 1986).

Other phenoclimatic models that have been put forward have mainly dealt with correcting the unreliability of the CU model in climates having mild or warm winters (Buchanan *et al.,* 1977; Erez *et al.,* 1979a; Gilreath and Buchanan, 1981; Shaltout and Unrath, 1983; del Real Laborde, 1987). Shaltout and Unrath (1983), working with cv. Starkrimson Delicious apple and from the findings of Erez and Lavee (1971) and Erez *et al.,* (1979a), developed what is termed the

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North Carolina (NC) model with a stronger negative effect for high temperatures. Yet, despite the uncertainty attaching to the validity of both the Utah and NC models as they take into account neither the differing responses to chilling of vegetative and flower buds nor the varying antagonistic effect of high temperature, which depends on the length of the low-temperature cycle (Erez *et al.,* 1979b; Scalabrelli and Couvillon, 1986), they are still applied more often than others. Recently, Fishman *et al.,* (1987a, b) devised a 'dynamic' model that includes the parameters and limits of earlier models.

The WCR of several orchard cultivars in Italy's mild-wintered southern and insular regions may not be satisfied (Crescimanno, 1960, 1964; Fatta Del Bosco, 1968). The recent spread of orchard crops to these areas has resulted in a rapid and sometimes uncontrolled introduction of foreign cultivars that have not been adequately tested beforehand. It is thus necessary both to investigate further the WCR of such cultivars and to learn more about the climatic potential of the various fruit-growing environments to prevent errors of WCR assessment. Current information in this regard is either limited or lacking altogether.

Caruso *et al.,* (1989) have advocated the application of phenoclimatic models, arguing that a more detailed knowledge of climate dynamics, on which current models are based, would help to determine a given environment's potential to meet the temperature requirements of several fruit species. The insights thus gained would be useful in selecting the species and cultivars best suited to given local conditions, in achieving optimum quantitative and qualitative traits in production and in determining the optimum dates to protect trees with plastic film and to apply restbreaking chemicals. The present study is a preliminary investigation of phenoclimatic models. It employed eleven areas of Sicily to determine the characteristics of prevailing temperature patterns and their viability for orchard production.

2. Materials and Methods

Hourly temperature readings (Fig. 1) were recorded form thermographs of the Palermo Civil Engineering Hydrographic Service ('Servizio Idrografico del Genio Civile di Palermo'). The data were taken from stations in the Service's network that fell within the altitude range from sea level to 500 m asl, i.e. the one currently in use for fruit orchards, and that had records available for the selected period in the years 1984-87. Only the data covering the biologically critical period of 1 November-31 March in these years were employed.

The models used for temperature conversion were the CH (Weinberger, 1950), the Utah (Richardson *et al.,* 1974) and the NC (Shaltout and Unrath, 1983). The latter two were used to calculate CUs, the Asymcur model to calculate GDHs (Anderson *et al.,* 1986) and the CH was applied to the overall 1 November-31 March period. CU calculation was begun as per the Utah model on the day after that on which the maximum negative CU accumulation was recorded; GDH calculation started the day after a given CU threshold (200, 400 and 800 CUs) was recorded and continued up to 31 March of each year. The number of days needed in the various environments to attain three thresholds of WCR and HR (4,000, 6,000 and 8,000) and the dates on which these conditions were met were also recorded.

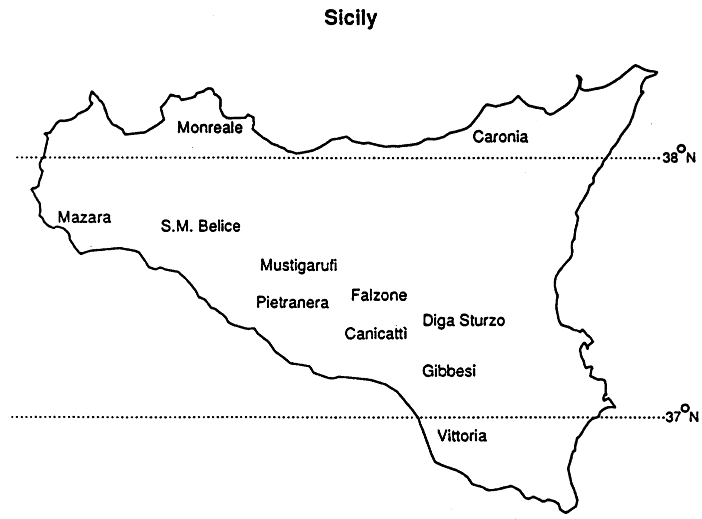

Fig. 1 – Site map of the thermometric stations used in this study.

The difficulties and costs involved in recording and analysing hourly temperature led to the testing of two methods that simulate hourly temperature change from the recorded minumum and maximum daily temperatures. The first, which assumes that the minimum occurs immediately before sunrise and the maximum at 2:00 pm, calculates the hourly values by linear interpolation from the minimum temperatures of two consecutive days and the intervening maximum temperature. The second employs a sine-logarithmic model developed by Linvill (1990) to compare estimated vs. recorded values of daily accumulated CUs (NC model) and CHs by regression analysis and Student's *t*-test for b0 = 0 and b1 = 1. To define associations within parameters between climatic sites and to identify pattern similarities, the main phenoclimatic variables (NC model) were standardized and subjected to principal components analysis.

3. Results and Discussion

Figure 2 shows the three CU levels as per the NC and Utah models. Only the 4,000 GDH threshold is given to illustrate the accumulation estimate. Table 1 shows that the Canicattì and Gibbesi sites had the highest accumulation of hours below 7.2°C and Mazara, the only site close to sea level (80 m asl), the lowest; the accumulation from year to year at the other sites varied markedly as a rule. It can thus be expected that cultivars having a WCR > 200 CHs will encounter problems at Mazara and those having a WCR

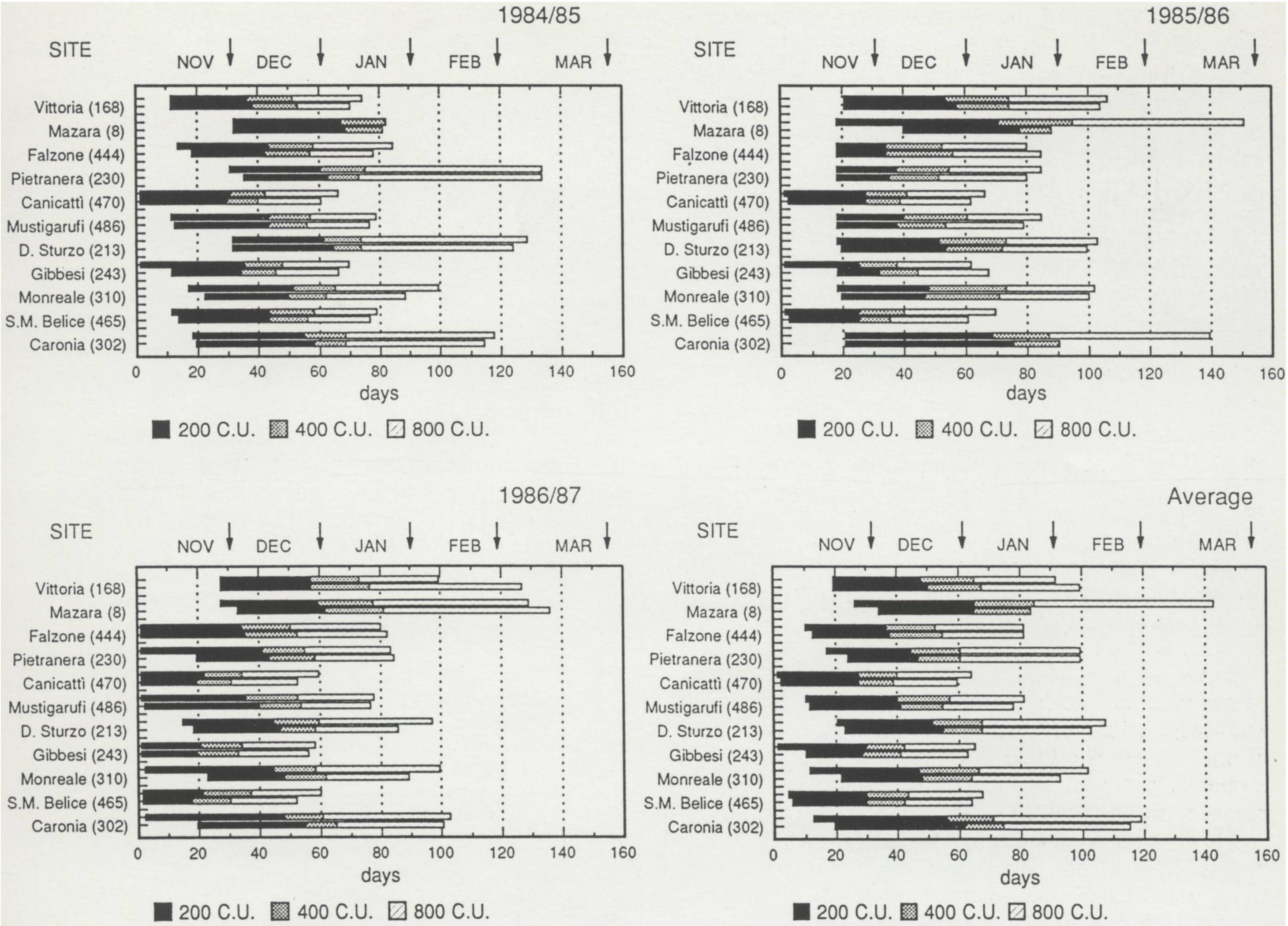

Fig. 2 – Dynamics of chill unit (CU) accumulation after the North Carolina model (N.C. *upper bar*) and Utah (*lower bar*) model beginning the day after maximum negative accumulation.

> 400-500 CHs will meet deficits at Caronia, D. Sturzo, Monreale and Vittoria; the remaining sites should be suitable for CUs at medium-to-high WCR.

Figure 2 indicates that the two models have similar responses to the dynamics of accumulated CUs, although in some cases there was a different estimate of accumulation start date and/or end date at the 800 CU highest threshold. A comparison of the surveyed sites shows that the start date, duration and, hence, completion date of the calculated WCR differed significantly. Accumulation start date is important and coincides, by definition, with the day after maximum negative accumulation. While the event regularly took place in early November at the Canicattì and Gibbesi sites, at the warmest ones it fluctuated from year to year, frequently occurring about 20 November. The dynamics involved in reaching the first CU level (200) are important in attaining the subsequent stages.

The intermediate threshold (400), which was attained at all sites in the three years but rarely after the end of January, usually seemed marked by an intense CU accumulation and, if we consider only the time interval from the end of 200 CU accumulation, all the sites showed it as the shortest phase. This was as expected, since the accumulation period is usually the coldest of the year, and contrast with the substantial differences shown by sites from 400 to 800 CUs. Those that went over 400 CUs early continued to accumulate them in a comparatively cold period of the year and soon reached the next threshold, whereas the warmer sites, which surpassed the 400 CU threshold later in winter, either registered an inevitable delay in reaching the next threshold or, like Mazara, never achieved it at all.

Table 1 – Number of hours below 7.2°C (Nov 1 – Mar 31).

Site	Altitude m a.s.l.	1984/85	1985/86	1986/87	Average	SD	CV
Vittoria	168	683	240	372	431	227	52
Mazara	8	98	161	299	186	102	55
Falzone	444	1024	1219	1189	1144	105	9
Pietranera	230	293	802	1048	714	385	53
Canicattì	470	1775	1715	1902	1797	95	5
Mustigarufi	486	993	756	852	867	119	13
D. Sturzo	213	152	384	575	370	211	57
Gibbesi	243	1383	1607	1883	1624	250	15
Monreale	310	520	397	632	516	117	22
S.M. Belice	465	838	814	1775	1142	548	47
Caronia	302	286	179	610	358	224	62
Total						217	36

Figure 3, 4 and 5 show the dynamics of GDH heat accumulation. The sites termed 'warmer' were expected to exhibit a rapid GDH accumulation even in the period pursuant to CU acquisition. As a rule, the longer the CU accumulation period, the shorter the period needed to meet the HR given the site's increasing temperature. Only 20 days needed in some cases to accumulate 4,000 GDHs. Cooler sites on the other hand exhibited difficulty in acquiring 4,000 GDHs, and in years of higher CUs some did not reach them by 31 March, i.e. 90 days from WCR completion. Yet even in some warmer sites like Mazara 4,000 GDHs were not attained by 31 March because the highest CU threshold was reached near the end of the WCR period, although for the lower CU levels of 200 and 400 Mazara achieved the 4,000 GDHs before all the other sites. If, however, one calculates the date by which accumulation occurred rather than its duration using either low or high CU levels, Mazara was the fastest to accumulate but not the earliest site to reach 4,000 GDH: in both models a cultivar with a WCR of 200 to 400 CUs would flower earlier at Falzone, Monreale or D. Sturzo than at Mazara.

Viewed form the CU and GDH thresholds, the warmer sites were not necessarily earlier than those only moderately cooler, although the coldest sites like Canicattì, Gibbesi and S. Margherita Belice were always later as their temperatures were lower over the surveyed period. Yet it should be borne in mind that a more advanced earliness of flowering in environments only moderately cooler than others exposes plants to a higher risk of frost injury during the most sensitive growth stages. This is why the minimum temperatures recorded over the three study years in the months of high frost risk are reported (Table 2). These data counsel caution in choosing low-chill cultivars for environments that at first glance seem to be a perfect match (e.g. Falzone). The earliness advantage afforded by low-WCR cultivars in such areas, as compared to areas like Vittoria that are well-known for early fruit production, would thus be uncertain. Other sites, especially Mazara and Caronia, would be unsuitable for cultivars with a WCR >/= 800 CUs, which would be better matched to environments similar to Falzone's and Mustigarufi's in which both requirement parameters would be met. For, though they can attain 800 CUs

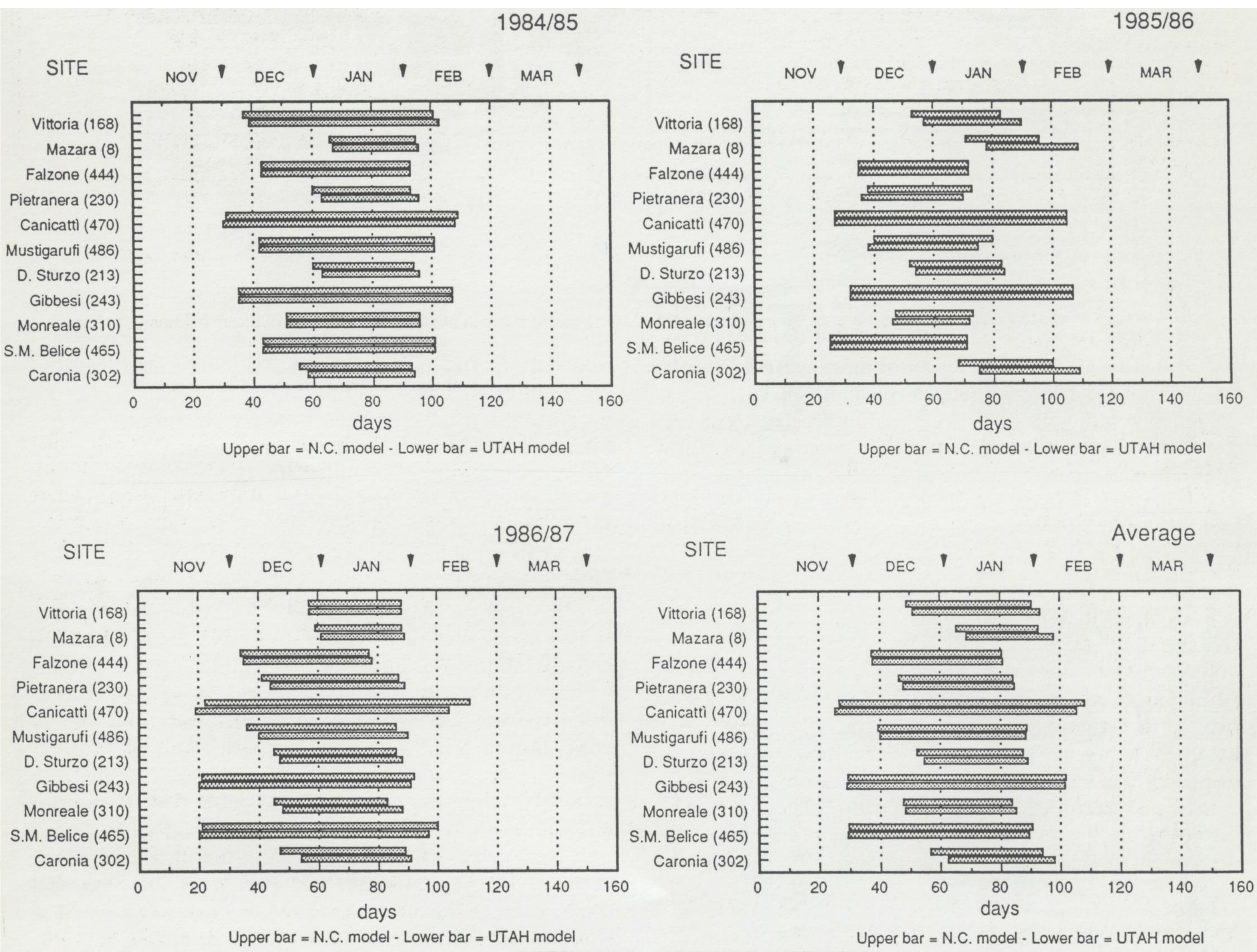

Fig. 3 – Dynamics of 4000 growing degree hours (GDH) accumulation starting from the date of 200 CU completion as calculated by the N.C. (*upper bar*) and Utah (*lower bar*) model.

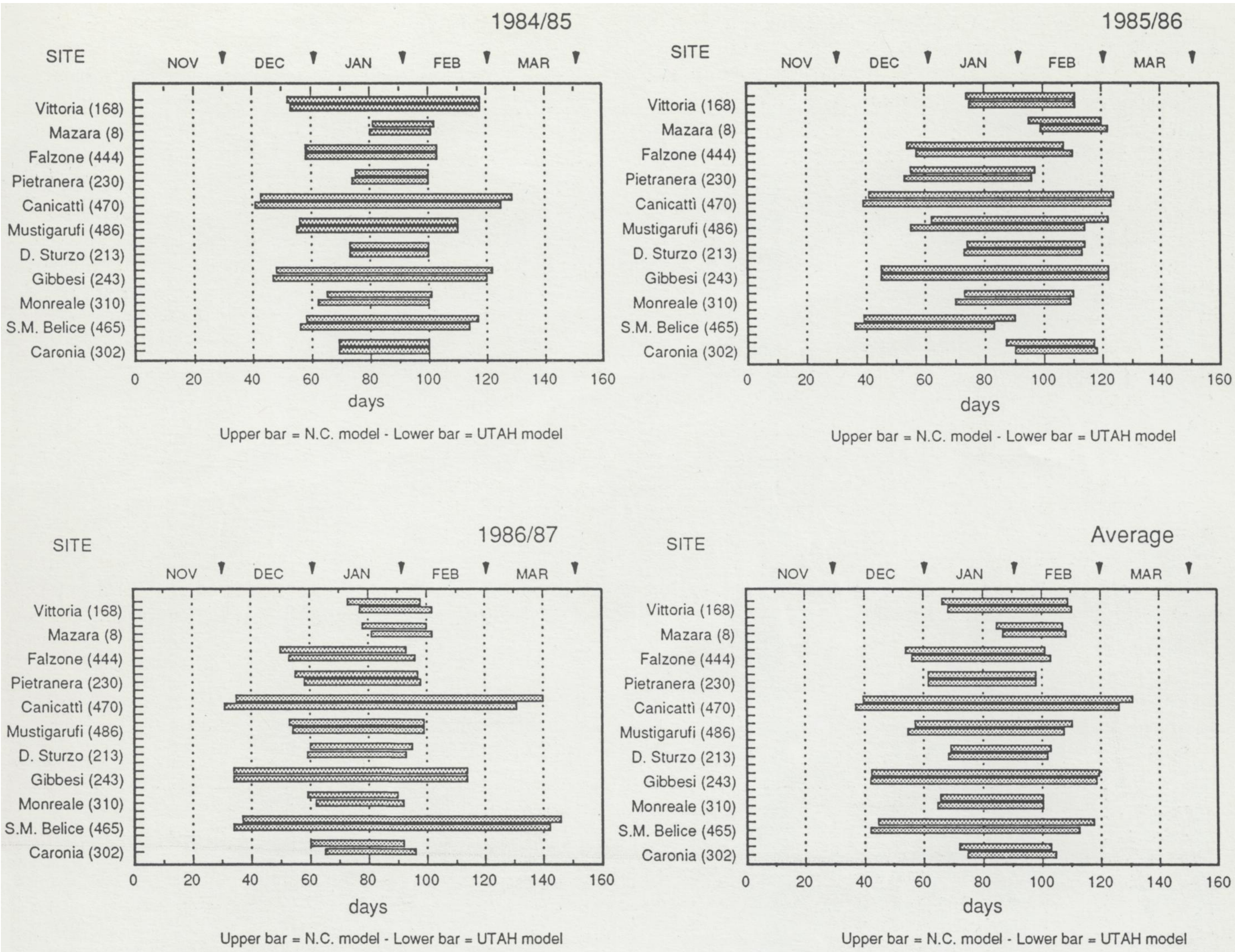

Fig. 4 – Dynamics of 4000 growing degree hours (GDH) accumulation starting from the date of 400 CU completion as calculated by the N.C. (*upper bar*) and Utah (*lower bar*) model.

early, at this WCR sites like Canicattì, Gibbesi and S. Margherita Belice do not meet adequate HR in time. While this obviously does not rule out the use of cultivars with a WCR of 800 CUs in such environments, it does suggest that flowering delay or deformity becomes more likely here than in other evrironments.

The statistical analysis summarizing the interrelationships of site and phenoclimatic variables (NC model) accounted for 76% of the total variation in two principal components. The weight of the single variables on the first component is similar (Table 3), even though there are two groups of variables that react in opposite directions. The first group has positive coefficients and includes the variables associated with the duration of CU accumulation; the second includes the duration of GDH accumulation.

Thus the coldest sites, which usually had faster CU and slower GDH accumulations, are found on the far left of the graph depicting the projection of the two principal components (Fig. 6): Canicattì, Gibbesi and S. Margherita Belice fall within this area while Mazara and Caronia (in 1985) are at the opposite side. This approach highlighted those sites whose phenoclimatic variables are so different as to evince opposite patterns and place the sites themselves at opposite sides of the graph. Yet it does not admit of a more detailed differentiation of sites in similar phenoclimatic areas, perhaps because relatively few years were involved and above all because site interrelationships varied considerably from year to year.

The daily temperature change as calculated from the two regression equations (Table 4) suggestes that the sine-logarithmic method (SLM) was better at estimating CU accumulation than the linear interpolation method (LM). Because the slopes of the regression equations are almost 1 in both models, the more accurate estimate of the SLM model is due to the intercept's being closer to 0. The difference accumulated over the 151-day survey period was only 150 CU when calculated by SLM as compared to actual CU accumulation; SLM also provided a more accurate CH estimate, for which LM showed even greater differences than in CU assessment.

Table 2 – Absolute minimum temperature per ten days.

Site	January			February			March		
	I	II	III	I	II	III	I	II	III
	2.9	0.5	3.0	2.2	5.0	5.0	6.8	4.0	7.0
Vittoria	5.0	4.0	4.5	5.0	3.0	8.0	8.0	8.5	5.5
	3.0	4.0	5.0	5.0	7.0	6.0	0.0	1.0	5.5
	5.5	3.5	6.5	7.5	10.0	5.0	8.0	7.0	8.0
Mazara	6.5	4.0	3.5	6.5	4.0	10.5	2.5	8.0	7.5
	4.0	6.5	6.0	7.0	6.0	6.0	1.5	3.0	7.0
	0.0	-2.7	1.6	1.0	1.9	1.0	0.4	1.4	1.0
Falzone	-2.2	0.2	-3.0	-1.2	-2.8	4.0	3.7	3.0	2.1
	-0.3	-3.4	-0.3	-1.0	-1.8	0.0	-3.5	-3.3	-1.2
	5.0	1.5	5.0	4.5	7.0	4.0	5.0	4.0	4.0
Pietranera	1.0	-1.0	-1.0	1.5	0.5	6.0	3.0	4.0	3.0
	-0.5	-3.0	-1.0	-1.0	1.0	-1.0	-2.0	-4.0	-2.0
	0.0	-3.0	2.5	2.0	4.0	-0.5	2.0	-2.0	2.0
Canicattì	0.0	-1.0	-3.0	1.0	-3.0	3.0	3.0	2.5	2.5
	1.0	-1.0	-0.3	1.0	2.0	-1.0	-3.0	-4.0	2.0
	2.0	-0.5	4.0	5.0	6.5	1.5	4.0	0.5	4.5
Mustigarufi	3.0	2.0	1.0	2.0	-1.0	5.0	3.5	4.5	4.0
	1.0	1.0	4.0	5.0	5.0	3.0	0.0	-1.0	4.5
	5.0	2.5	7.0	6.0	7.0	6.5	8.0	6.0	8.0
D. Sturzo	5.0	3.0	2.0	4.0	1.0	8.0	7.5	6.5	3.5
	3.5	0.5	4.5	4.0	5.0	3.0	1.0	2.0	5.7
	0.0	-1.0	3.0	0.0	3.0	1.0	1.0	-0.5	1.0
Gibbesi	0.0	-3.0	-4.0	-1.0	-2.0	4.0	0.0	2.0	-1.0
	0.0	-5.0	-1.0	-2.0	1.0	-2.0	-6.0	-6.0	-2.0
	3.0	0.0	3.5	2.5	7.0	2.0	4.0	4.0	5.0
Monreale	5.0	3.5	1.5	5.0	3.0	6.0	6.0	5.0	5.0
	3.5	4.0	2.5	5.5	6.0	4.0	0.0	0.5	4.0
	0.0	1.1	4.9	5.0	6.6	3.4	6.0	0.9	4.3
S.M. Belice	5.9	4.9	2.4	4.0	0.3	6.2	6.9	6.0	5.3
	-0.8	1.3	3.0	2.5	2.0	1.0	-3.1	-1.6	2.1
	4.0	2.0	7.8	8.0	7.4	5.0	7.0	3.8	8.8
Caronia	7.0	7.0	3.0	6.6	1.8	7.6	9.8	9.0	6.5
	1.0	1.5	6.5	7.0	7.2	5.0	1.2	1.2	7.0

Ten days in columns, year in rows: top 1985, center 1986, base 1987.

Table 3 – First two principal components loadings.

Phenoclimatic variable:	Comp. 1	Comp. 2
Date of beginning of CU calculation	0.298	-0.196
Length of 200 CU accumulation	0.277	0.528
Length of 400 CU accumulation	0.322	0.442
Length of 800 CU accumulation	0.367	0.281
Length of 4000 GDH accum. (200 CU)	-0.426	0.019
Length of 4000 GDH accum. (400 CU)	-0.434	0.093
Length of 4000 GDH accum. (800 CU)	-0.307	0.040
Predicted blooming date (200 CU)	-0.211	0.519
Predicted blooming date (400 CU)	-0.296	0.303

4. Conclusions

The heterogeneity highlighted by the more common phenoclimatic models used for the environments surveyed illustrates the considerable variety of Sicily's cultural areas and explains the wide range of fruit species and cultivars than can be found there. Remarkable differences emerged in accumulated CUs as well as in the start and end dates of specific requirements among sites over the period examined. As the principal component analysis indicated, the sites studied

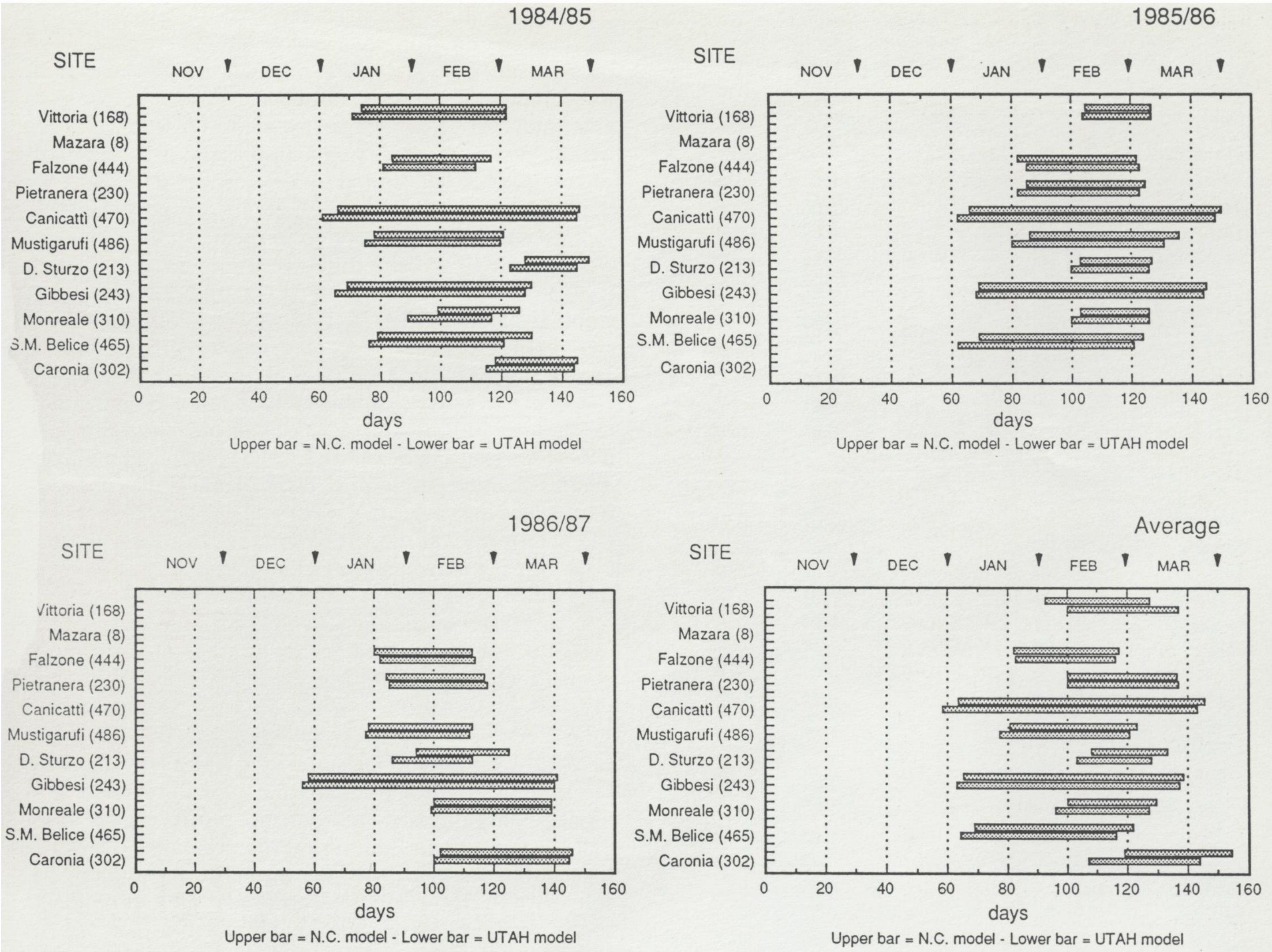

Fig. 5 – Dynamics of accumulation of 4000 Growing Degree Hours (GDH) starting from the date of completion of 800 CU calculated by North Carolina model (N.C.; *upper bar*) and Utah model (*lower bar*). Some averages are calculated from only two years due to non-completion of GDH requirement by March 31 st.

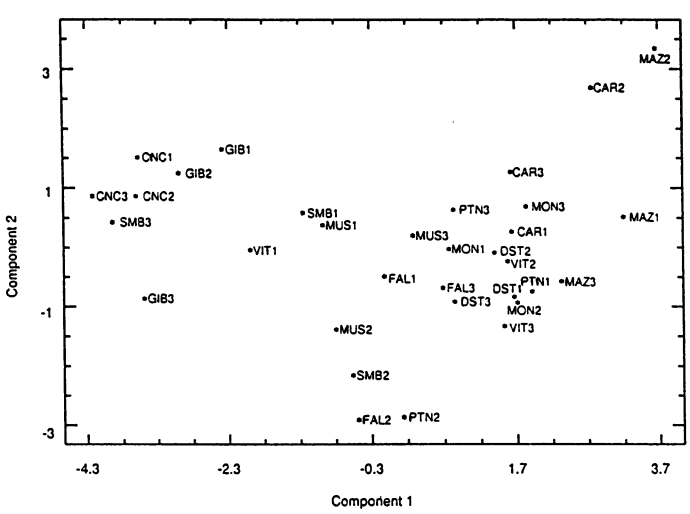

Fig. 6 – Plot of the two principal components of the given phenoclimatic variables. The numeric suffix is referred to the year of observation, i.e.: 1=1984/85 2=1985/86 3=1986/87.

showed three general CU accumulation patterns: early and intense chilling accumulation, its opposite (resulting in a long accumulation period) and an intermediate one.

The dynamics of GDH accumulation exhibited a strong dependence on CU accumulation. Here, again, more than one general pattern was found: low-intensity GDH accumulation at the coldest sites (Canicattì and Gibbesi), the opposite at the warmest sites of Mazara and Caronia, while the remaining sites evidenced complementary aspects to the former patterns rather than clear distinctions from year to year in the development of the two accumulation phenomena. At these sites, e.g. Falzone and Monreale, significant signs of earliness can be expected, which in some cases even show a greater potential earliness than the warmest sites. Although this is surprising because it contradicts the belief that coastal areas are the earliest, it confirms the performance of cvs. 'Springtime' (Crescimanno & Fatta del Bosco, 1963) and 'Springcrest' (Caruso *et al.*,

Table 4 – Parameters of the regression equations between daily accumulated CU (N.C. model) and CH calculated by the two interpolation models and by observed values.

Chill unit (CU)			Linear interpolation		
	b0	SE	b1	S.E.	r-square
Vittoria	-1.07 ***	0.13	1.02 NS	0.01	0.94
Mazara	-1.67 ***	0.11	1.02 *	0.01	0.94
Falzone	-1.56 ***	0.23	1.04 *	0.02	0.86
Pietranera	-1.29 ***	0.15	1.03 *	0.01	0.94
Canicattì	-2.24 ***	0.29	1.07 ***	0.02	0.88
Mustigarufi	-2.17 ***	0.16	1.06 ***	0.01	0.94
D. Sturzo	-1.82 ***	0.12	1.05 ***	0.01	0.96
Gibbesi	-1.12 ***	0.29	1.02 NS	0.02	0.86
Monreale	-2.24 ***	0.18	1.05 **	0.02	0.92
S.M. Belice	-1.31 ***	0.21	1.02 NS	0.01	0.92
Caronia	-2.63 ***	0.14	1.06 ***	0.01	0.94
			Sine-logarithmic interpolation		
	b0	SE.	b1	S.E.	r-square
Vittoria	-0.20 NS	0.13	1.00 NS	0.01	0.94
Mazara	-0.60 ***	0.11	0.99 NS	0.01	0.94
Falzone	-0.29 NS	0.21	0.99 NS	0.02	0.86
Pietranera	0.06 NS	0.15	0.97 *	0.01	0.92
Canicattì	-0.91 ***	0.24	1.02 NS	0.01	0.92
Mustigarufi	-1.12 ***	0.16	1.03 *	0.01	0.94
D. Sturzo	-0.64 ***	0.12	1.00 NS	0.01	0.94
Gibbesi	0.28 NS	0.32	0.95 *	0.02	0.83
Monreale	-1.11 ***	0.18	1.00 NS	0.02	0.90
S.M. Belice	-0.53 **	0.20	1.00 NS	0.01	0.92
Caronia	-1.68 ***	0.14	1.03 *	0.01	0.94
Chilling hours (CH)			Linear interpolation		
	b0	SE.	b1	S.E.	r-square
Vittoria	-0.03 NS	0.09	0.83 ***	0.02	0.86
Mazara	0.07 NS	0.01	0.63 ***	0.02	0.76
Falzone	0.43 *	0.21	0.68 ***	0.02	0.69
Pietranera	0.09 NS	0.14	0.77 ***	0.02	0.69
Canicattì	-1.93 ***	0.25	0.97 NS	0.02	0.87
Mustigarufi	-0.32 *	0.15	0.82 ***	0.02	0.95
D. Sturzo	-0.05 NS	0.09	0.73 ***	0.02	0.79
Gibbesi	-0.41 NS	0.25	0.89 ***	0.02	0.83
Monreale	-0.12 NS	0.11	0.74 ***	0.02	0.81
S.M. Belice	-0.45 ***	0.17	0.87 ***	0.01	0.89
Caronia	-0.12 NS	0.09	0.81 ***	0.01	0.87
			Sine-logarithmic interpolation		
	b0	SE.	b1	S.E.	r-square
Vittoria	0.39 **	0.13	0.92 ***	0.02	0.81
Mazara	0.26 **	0.09	0.82 ***	0.03	0.68
Falzone	1.49 ***	0.25	0.78 ***	0.03	0.66
Pietranera	0.98 ***	0.19	0.83 ***	0.03	0.70
Canicattì	0.07 NS	0.20	0.93 ***	0.01	0.90
Mustigarufi	0.44 **	0.16	0.86 ***	0.02	0.84
D. Sturzo	0.34 **	0.12	0.85 ***	0.02	0.73
Gibbesi	1.60 ***	0.27	0.85 ***	0.02	0.80
Monreale	0.40 **	0.14	0.80 ***	0.02	0.76
S.M. Belice	0.30 NS	0.17	0.89 ***	0.01	0.89
Caronia	0.07 NS	0.10	0.86 ***	0.02	0.87

***, **, *, NS. Significant at the 0.1%, 1% and 5% level and not significant, respectively.

1989), which responded better and matured earlier in areas slightly further inland. In other words, Sicily's coastal areas may not be, as is generally held, the earliest unless cultivars with very low WCR (<200 CUs) are employed.

Our data show the need for climatic evaluation of the cultural environment and WCR determination of species and cultivars. The methods employed herein to estimate CHs and CUs often did not prove comparable and require further assessment. Though valid for the former purpose, CH accumulation, which is still used for WCR determination of cultivars as well as for the evaluation of crop environment, proved unsuitable for rest-break chilling evaluation, especially when applied to environments differing from those for which it was originally developed (Erez and Lavee, 1971). Confirmed too is the high variability inherent in the CH method, as has been reported for other environments (Richardson *et al.,* 1974; Shaltout & Unrath, 1983). And, while this variability cannot be attributed to the normal climatic variations of our environments, it suggests that the use of the CH approach in environmental characterization be reconsidered. Field observation and phenological data are necessary to validate CU determination models for predictive use. A national working group has been conducting such studies in Italy since 1988.

That both models were found capable of distinguishing sites bound by specific environmental restrictions on fruit growing shows the methodological approach pursued in the present study to be a viable tool in survey work for site and cultivar selection in given geographical areas. This approach also made it possible to verify the relative reliability for our sites of two models that simulate hourly temperature change from daily maximum and minimum temperatures. The sine-logarithmic method provided the most encouraging results, while its degree of accuracy and consequent speed of calculation will enable further analysis of temperature data over a thirthy-year period from a number of sites. Current research is supplying more detailed information for the characterization of climatic areas and for integration with other bioclimatic and pedological parameters that are useful in defining more complex models of site 'suitability'.

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