15C.5 PHENOLOGICAL RESPONSES OF PEAR TREES TO HEAT UNITS

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1. INTRODUCTION

Pear tree phenological dates and climatic data were collected near Oristano and Tempio on the Italian island of Sardinia (Italy), and they were analyzed to identify the best threshold temperature and cumulative degree-day requirement to predict the number of days from budbreak (BB) to bloom (BL), fruit set (FS), and ripening (RI). The threshold temperatures were selected to minimize the absolute value of the difference between predicted and observed days from BB to the various phenological stages. In most cases, the degree-day based phenological predictions were considerably better than using the mean calendar date. However, there was only a small benefit when the observed dates varied little from year-to-year. In the one case when heat units did not improve the prediction over using the mean observed number of days between the stages, all year but one were predicted well. If heat units explain all of the variation in development from year-to-year, there should be no relationship between cumulative degree-days and days between phenological stages. However, in all cases, the cumulative degree-days between phenological stages were found to increase with increasing days between stages. This is indicative that other factors in addition to heat units are affecting development.

2. METHODS

Phenological dates of budbreak (BB), bloom (BL), fruit set (FS), and ripening (RI) were collected from four varieties of pear orchards on the island of Sardinia during the period 1992-1995 at a high elevation inland site in the north near Tempio and at a low elevation site in the west central coast near Oristano. The average phenological dates for the varieties Butirra, Coscia, S. Maria, and Precoce di Fiorano are presented for the two locations in Table 1. Mean daily maximum and minimum temperature data for the four years are shown in Figure 1.

Heat units were calculated using the single-sine wave method (Zalom et al., 1983) and the optimal lower threshold temperatures were determined for each variety using the four years of data from the two sites. The sum of degree-days between the phenological stages is relatively constant from year-to-year, whereas the number of days between stages is variable. Therefore, when using the pear development dates and climate data, the goal is to find a threshold temperature and the mean observed cumulative degree-days that will give the smallest possible difference between predicted and observed days. For example, Figure 2 shows the predicted and observed days between BB and FS for the Butirra pear variety. If heat units were not used, then the mean number of days between the BB and FS would be used to estimate when FS will occur. For degree-days to be useful, the mean absolute value of the difference between predicted and observed days from BB to FS must be smaller than the mean absolute value of the differences between observed days and the mean of the observed days. To find the best heat unit prediction of the days from BB to FS, the threshold temperature is varied until the mean absolute value of the difference between predicted and observed days is minimized. Trial and error was also used to test for an upper threshold temperature, but no upper threshold was identified.

Table 1. Mean phenological dates for budbreak (BB), bloom (BL), fruit set (FS), and ripening (RI) during the period 1992-1995 near Tempio and Oristano.

Variety	BB	BL	FS	RI
TEMPIO (40° 55' N 9° 07' E 550 m a.s.l.)				
Butirra	2-Mar	5-Apr	20-Apr	5-Aug
Coscia	2-Mar	6-Apr	22-Apr	1-Aug
S. Maria	9-Mar	13-Apr	29-Apr	7-Aug
Precoce	4-Mar	7-Apr	23-Apr	21-Jul
ORISTANO (39° 53' N 8° 37' E 15 m a.s.l.)				
Butirra	2-Mar	6-Apr	22-Apr	1-Aug
Coscia	9-Mar	13-Apr	29-Apr	7-Aug
S. Maria	4-Mar	7-Apr	23-Apr	21-Jul
Precoce	2-Mar	5-Apr	20-Apr	5-Aug

3. RESULTS AND DISCUSSION

The mean daily minimum temperature was similar at the two sites, but the mean daily maximum temperature was clearly higher in Oristano during the fall, winter, and spring (Figure 1). As a result, one would expect the pears to develop faster in Oristano than in Tempio. However, there was no consistent difference in phenological development rate between the two sites (Table 1).

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Using the trial and error method to determine the best threshold temperatures, a comparison between using heat units to predict the days from BB to BL, FS, and RI and using the mean observed days is shown in Table 2. In all cases, except BB to RI for Coscia, the heat unit prediction was better than using the mean observed number of days. Even for the Coscia variety from BB to RI, the prediction was better than using the mean observed days in most years. Only one year was an outlier, and the discrepancy could be the result of sampling error. The results for other stages and varieties were generally similar to those shown in Figure 2 for BB to FS for the Butirra variety. The predicted days between stages was similar to using the mean observed days for the S. Maria variety, but the mean absolute value of differences from the mean was small for that variety.

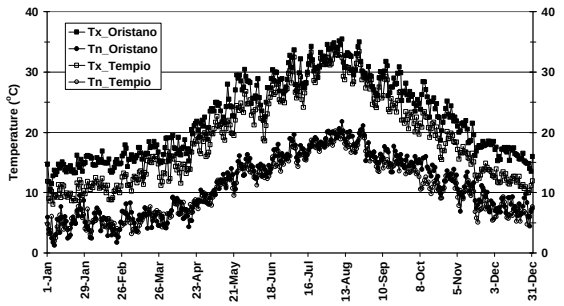

Figure 1. Mean daily temperature for 1992-1995 at Oristano maximum (■) and minimum (•) and at Tempio maximum (□) and minimum (o).

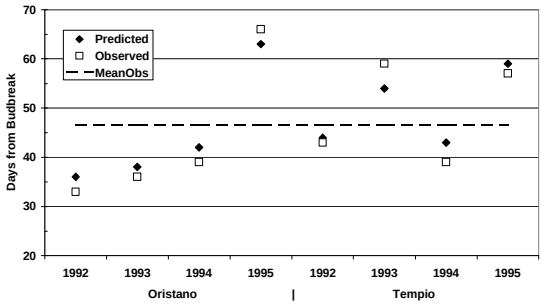

Figure 2. Observed, mean observed, and predicted days from budbreak to fruit set for the Butirra pear variety. The predicted values were calculated using the single-sine method and a threshold temperature $T_L = 5^oC$.

Although good results were found for the heat unit predictions, there is room for improvement in modeling of phenological development. This is clear in Figure 3, which shows the regression of cumulative degree-days versus observed days between BB and FS for the Butirra variety. Similar results were found for all varieties and stages. A plot of cumulative degree days versus observed days should have a slope and R^2 equal to zero, so these results indicate that other factors (e.g., rainfall, irrigation) are also impacting development.

Table 2. Optimal threshold temperatures (T_L) and the absolute value of the difference between observed and predicted days from budbreak to bloom (BL), fruit set (FS), and ripening (RI) with the mean absolute value of the difference between observed and the mean observed days in brackets.

Variety	T_L (^oC)	BL	FS	RI
Butirra	5	5.1(9.2)	2.9(10.6)	4.3(11.0)
Coscia	3	4.5(8.3)	3.4(9.4)	7.0(6.5)
S. Maria	3	5.3(6.1)	3.3(5.5)	3.5(5.1)
Precoce	4	2.6(5.8)	3.5(6.4)	2.8(7.8)

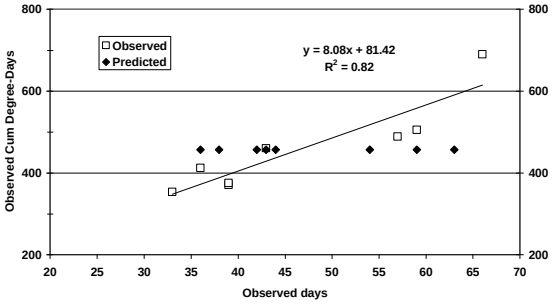

Figure 3. Observed cumulated degree-days versus observed days between BB and FS for the Butirra pear variety.

4. CONCLUSIONS

Phenological dates for four pear tree varieties and climate data from two locations were used to determine the threshold temperatures and the cumulative degree-days needed to provide good predictions of days from budbreak to bloom, fruit set, and ripening. Threshold temperatures were identified by minimizing the mean of the absolute values of difference between predicted and observed number of days over years and locations. Although the results were good, a correlation between cumulative degree-days and number of days between phenological stages is indicative that other factors in addition to heat units are affecting development.

5. ACKNOWLEDGMENTS

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6. REFERENCES

Zalom F.G., Goodell P.B., Wilson W.W. and Bentley W.J. 1983. Degree-Days: The calculation and the use of heat units in pest management. Leaflet 21373. Division of Agriculture and Natural Resources, University of California.