Some Climatic Indices for Pinot noir Maturation at a Meteorological Station in Burgundy*

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This paper deals with relationships between climate and vineyard at a meteorological station in the wine-growing area of Burgundy. Statistical analyses were carried out on data for the 1975-1996 period. Climatic indices for Pinot noir grape harvests were developed for the 1975-1990 period using a composite analysis. These revealed that high spring temperatures, after a dry winter, led to an early date of Pinot noir harvest, whereas low spring temperatures, after a rainy winter, led to a late date of harvest. These indices proved to be accurate for the 1991-1996 period. The date of Pinot noir harvest could be estimated as early as May, before flowering, using these indices and linear regression methods for the 1975-1996 period. Results showed that the differences between real and estimated harvest dates were as little as five days.

The weather is a major variable in wine-growing. Many people have estimated the climatic potentialities of wine-growing areas all over the world (Branas *et al.,* 1946; Winkler *et al.*, 1974; Huglin, 1978) and have investigated the relationship between climate and vineyard performance (in France, for example, Pouget, 1988; Carbonneau, 1992). Most of the indices used are thermal indices for the growing season. The effect of rainfall, and particularly winter rainfall, is less obvious, even if measured in terms of the water balance.

Research on climate and vineyard performance has been mainly orientated towards acquiring knowledge about maturation in order to forecast the volume and date of harvest (Besselat, 1987; ANON, 1992). Therefore climatic indices for Pinot noir grape date of harvest were investigated using a simple experiment at a meteorological station in Burgundy located just north of Beaune at Savignylés-Beaune (Fig. 1). Savigny is a pest control station in the Burgundy area, 40 km south of Dijon, which has been in operation for many years. Phenological records date back to 1930 but climatic data have been collected only since 1975.

MATERIALS AND METHODS

Statistical analyses of dates of harvest and climatic data were carried out for a sixteen-year period from 1975 to 1990. The remaining six years of data up to 1996 were then used to test the validity of the results. The Pinot noir date of harvest was observed at the pest control station. Climatic data were recorded at the meteorological station located in the vineyard of the pest control station and verified by the Meteo-France agency.

The first step was a correlation analysis for the period 1975-1990 of the dates of harvest and several climatic elements which have a biological relevance for the vineyard. Research was done using anomalies on a monthly scale, and the Student t-test was used to verify the significance of the results. A strong linear correlation doesn't necessarily indicate a cause and effect relationship. The two variables can have a covariable relationship, being linked to an external phenomenon and not directly to each other. This is the case for rainfall, which induces particular phenomena such as the bursting of berries and has a major influence on the soil water balance.

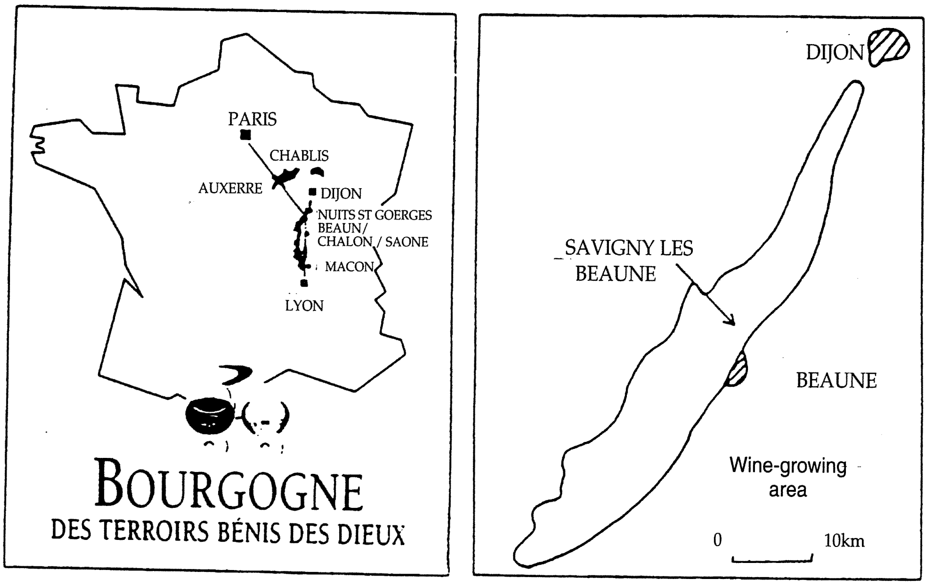

FIGURE 1
The Burgudian wine-growing area.

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The best correlations were obtained following the method used by Gerbier & Remois (1977) in the Champagne area, using quality/quantity and climatic data, and only coefficients significant at 5% (*) and 1% (**) were utilised.

From the best climatic correlations some climatic indices were defined for the period 1975-1990 using a composite analysis. The values of early and late indices correspond to the composite of three years of early vintages (1976, 1989, 1990), that is before 20 September, and late vintages (1977, 1978, 1980), that is after 5 October. The two composites of three years are signficant samples for a sixteen-year period. The difference between them was tested using the Student t-test. Therefore, if |t| > 4,6 or 2,7; then the difference is significant at 1% (**) or 5% (*) respectively.

The last step consisted of testing the validity of the climatic indices on data from the period 1991-1996. A multiple regression was calculated by fitting linear regression models on the whole period 1975-1996 to estimate the date of Pinot noir harvests from the climatic indices.

RESULTS AND DISCUSSION

The average date of harvest (1975-1990) for Pinot noir in the Coté de Beaune wine-growing area is 27 September.

With regard to temperature and rainfall, the best correlation coefficients (Table 1) for the sixteen year period were obtained with the April-August average maximum temperature (-0,86**) and October-March winter rainfall total (0,65**). The prominent effect of temperature on "advancing" maturation is well known but not the "retarding" effect of winter rainfall.

The correlation between the April-August average maximum temperature and the date of harvest is shown in Fig. 2. When temperatures were above the norm (mean of the sixteen year period), the harvest was early (e.g. 1989 or 1990). When temperatures were below the norm, the harvest was late (e.g. 1977 or 1978).

With few exceptions, rainy winters resulted in later dates of harvest and dry winters resulted in earlier dates of harvest. (Fig. 3).

During the period of study the mean climatic indices for an early date of harvest, that is before 20 September, correspond to the climatic indices for 1976, 1989 and 1990. For example, the date of harvest will be early if the April-August average maximum temperature exceeds 22,5°C and if the winter is rather dry, with less than 300 mm rain from October to March. Conversely, the mean climatic indices for a composite of three late harvest years (1977, 1978 and 1980), that is after 5 October, are an April-August maxi-

TABLE 1

Climatic indices for the date of Pinot noir harvest in the Côte de Beaune area calculated using data from the 1997-1990 period.

Climatic indices	R	Average climatic index (1975-1990)	Value of the early climatic index (composite 1)	Value of the late climatic index (composite 2)	Student's t-test for the two composites
April-August maximum temperature (°C)	-0,86**	21.2	22,9	19,4	t = 12,4**
Number of days with maximum temperature above 25°C	-0,82**	47	68	29	t = 13**
May-August minimum temperature (°C)	-0,78**	12,5	13,4	11,6	t = 9,4**
Number of hours of sunlight from May to August	-0,72**	946	1114	827	t = 6**
Rainfall amount from October to March (mm)	0,65**	376	277	501	t = 7,6**

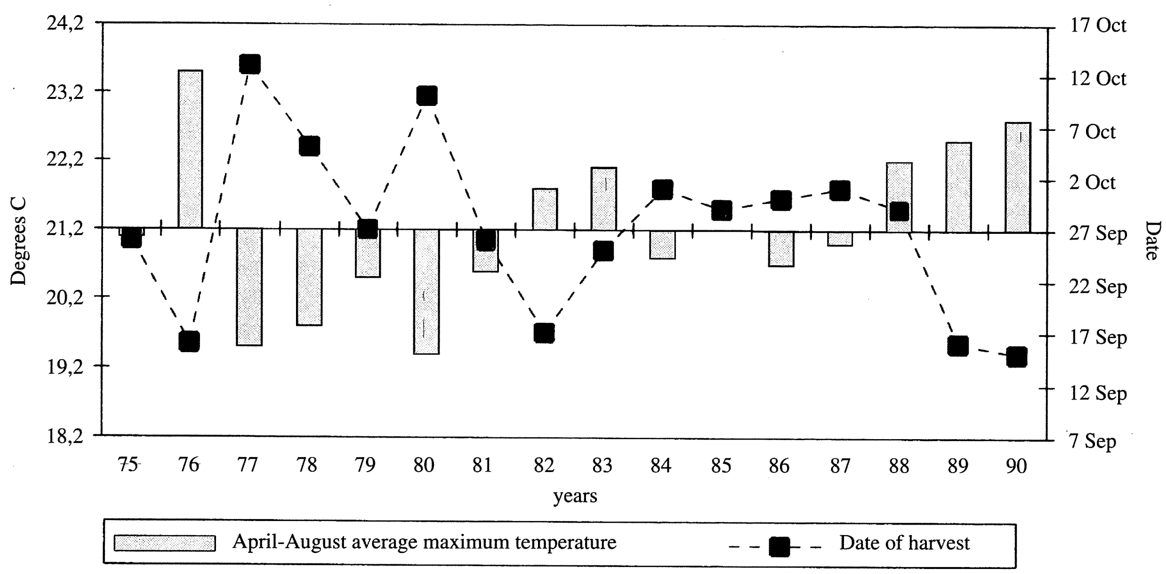

FIGURE 2
Correlation between average April-August maximum temperâture (mean = 21,2°C) and the date of harvest (mean = 27 September) for the 1975-1990 period. Pest Control Station, Savigny-lés-Beaune. R = -0,86**; R^2 = 0,74.

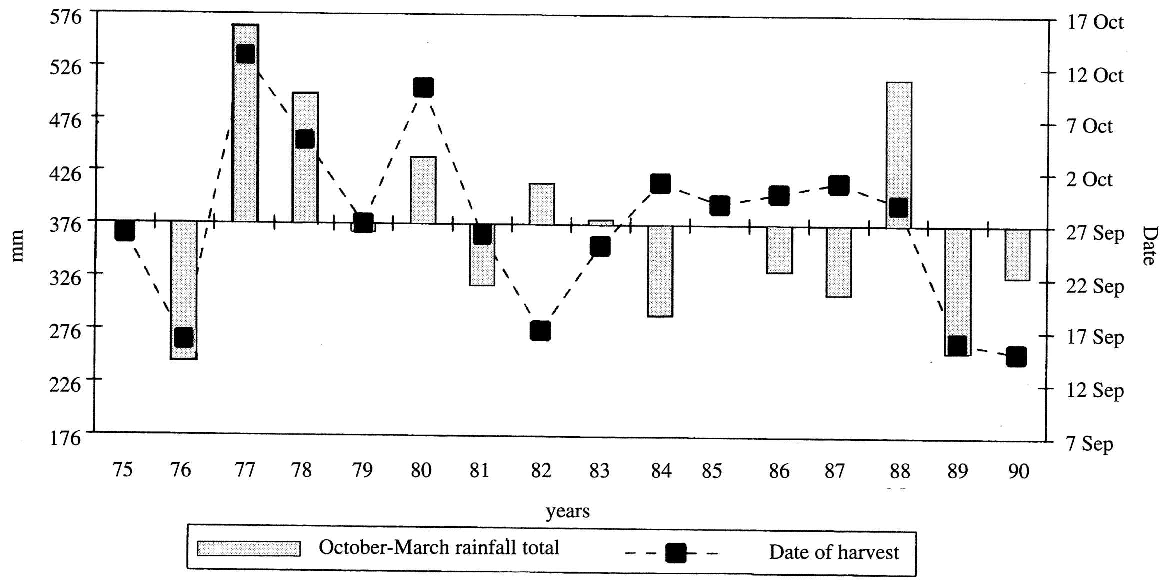

FIGURE 3
Correlation between October-March rainfall (mean = 376 mm) and the date of harvest (mean = 27 September) for the 1975-1990 period. Pest Control Station, Savigny-lés-Beaune. R = 0,65**; R^2 = 0,42.

TABLE 2

Values of the thermal index (May maximum temperature) and rainfall index (March rainfall amount) in accordance with the date of harvest during the 1975-1990 period.

Date of harvest during the 1975-1990 period	Value of the thermal index (°C)	Value of the rainfall index (mm)
LATE: after 5 October	16,9	66
MEDIUM: between 20-30 September	18,1	61
EARLY: before 20 September	21,7	31

TABLE 3

Climatic indices test of validity during the 1991-1996 period (Shaded if valid).

Year	Thermal index (°C)	Rainfall index (mm)	Date of harvest
1991	18,1	100	25 September
1992	22,6	44	17 September
1993	20,2	8	15 September
1994	20,0	19	16 September
1995	19,9	63	25 September
1996	18,0	18	20 September

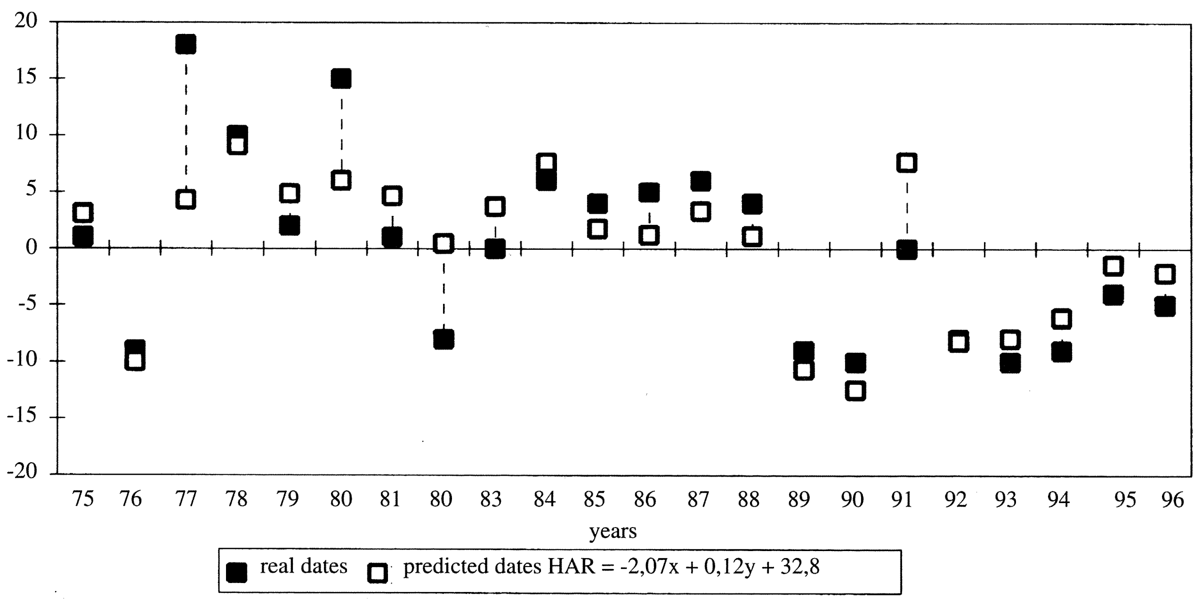

FIGURE 4
Comparison between real and predicted dates of harvest. Negative values are early dates and positive values are late dates of harvest. The zero line is the average date of harvest (27 September). Pinot noir grape, Côte de Beaune wine-producing area.

mum temperature of less than 20°C, and an October-March rainfall of greater than 500 mm.

From Table 1 it can be deduced that for the 1975-1990 climatic period, a decrease of 1,8°C (19,4-21,2°C) during April-August, combined with an increase of 125 mm (501 - 376 mm) in rainfall during autumn and winter, would result in harvest occurring one week later, on 5 October instead of 27 September. Similarly, an increase of 1,7°C (22,9-21,2°C) during April-August, combined with a decrease of 100 mm (277 - 376 mm) in rainfall during autumn and winter, would allow harvest to begin one week earlier, on 20 September instead of 27 September.

As the coefficients of correlation became significant as early as May for temperature and March for rainfall, these two indices were used to test the validity on the last six years of data.

During the period of study, late dates of harvest (after 5 October) corresponded to a rainfall index (March rainfall amount) of 66 mm and a thermal index (May maximum temperature) of 16,9°C; whereas early dates of harvest (before 20 September) correspond to a rainfall index of 31 mm and a thermal index of 21,7°C (Table 2). According to Table 3 the thermal index has been proved correct for the whole test period (1991-1996), and the rainfall index appears to be valid for estimating the date of harvest for four out of six years.

The correlation coefficient between May maximum temperature and March rainfall amount was not significant (-0,32). Therefore, these two climatic indices are independent and can be combined in a multiple regression computed in order to estimate the date of harvest.

The resulting regression equation for the harvest date estimation (HAR) is as follows: HAR = 2,07 x + 0,12 y + 32,8; where x represents the May maximum temperature and y the March rainfall amount (anomalies / 1975-1996 average).

The regressions performed on March rainfall and May maximum temperature were significant at 1%, with 47% of the variance explained by only the thermal index, increasing to 63% with both thermal and rainfall indices. There was a good relationship between the real and predicted date of harvest (Fig. 4). The margin of error of estimates is ± 5 days. Negative values correspond to early dates of harvest while positive values correspond to late dates. Only four years showed a poor estimate (i.e. 1977, 1980, 1982 and 1991). This is represented by the dotted lines between observed and predicted dates on the times series (Fig. 4). The dates of harvest were underestimated by 11 to 14 days in 1977 and 1980, and overestimated by one week in 1982 and 1991. The weather after May (date of estimation) during the whole fruit-growing period and before the harvest is also important, and can make or break a vintage.

For example, the whole growing period of 1977 was wet and cool until August. This explains why the actual date of harvest was later than that predicted. The summer of 1980 was very cool, whereas in contrast the summer of 1982 was very hot. In 1991 the growing season was rather cool and September recorded more rain than usual, leading to a later harvest than predicted.

CONCLUSIONS

The temperature in May has been shown to be a good predictive climatic index for both harvest and flowering (-0,71** and -0,79** respectively), which usually occurs during the middle of June. The correlation between harvest and flowering (0,83**) indicates that the period between the flowering and harvest is fixed at approximately 100 days in Burgundy.

The thermal index has been improved by including a rainfall index. The regression equation estimating the date of harvest by combining March rainfall and May maximum temperature shows that these indices can give a good indication of the date of harvest as early as May, in other words before flowering. These results represent an improvement in accuracy of ten days compared to the estimation of the Bureau Interprofessionnel des Vins de Bourgogne (ANON, 1992) by using an analysis of maturation.

The agronomic interpretation of the statistical relationship between winter rainfall and the date of harvest remains problematic. The rainfall index (March rainfall) can be explained in terms of its role in the water supply. Because vineyards need water stress, a below average rainfall in March seems to be beneficial for the whole water balance during the growing season.

These results require further investigation. They must be compared with existing published models and must also be tested at several locations, for different grapes, using more variables and longer periods of climatic and phenological data. Absolute accuracy of climatic records is essential and microclimatic influences cannot be underestimated.

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