HARVEST DATES – TEMPERATURE RELATIONSHIPS AND THERMAL REQUIREMENTS OF WINEGRAPE VARIETIES IN GREECE: OBSERVED AND FUTURE CLIMATE RESPONSES

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Abstract:

Context and purpose of the study - Air temperature is arguably one of the most decisive factors for winegrape varieties developmental cycle, ripening potential and yield. Taking into account that predicted future warmer conditions will possibly impose challenges in global viticulture, it is of outmost importance to understand the adaptive capacity of each variety in the current and future climate conditions. Thus, the objective of this study was twofold: (a)to investigate the relationships between air temperature during the ripening period and harvest dates for eight principally cultivated indigenous winegrape varieties (one for each winegrape region of Greece) and (b) to assess varieties' thermal demands (four varieties) using the standard growing degree day (GDD) formula and project harvest date in two future windows using a multi-Regional Climate Model ensemble dataset.

Material and methods - Harvest dates were assembled from four white [cvs. Muscat of Alexandria (Limnos), Assyrtiko (Santorini), Muscat blanc (Samos) and Athiri (Rodos)] and four red [cvs. Moschofilero (Tripoli), Mavrodaphni (Pyrgos), Mandilaria (Crete) and Xinomavro (Naoussa)] varieties, covering a period from 11 to 44 years. Daily observations of maximum (TX) and minimum (TN) air temperature were obtained from the Hellenic National Meteorological Service (HNMS) in order: (a) to investigate the relationships between harvest dates and temperature conditions during the ripening period and (b) to calculate growing degree days (GDD, ^{o}C units) for each variety. In addition, high resolution ensemble datasets (derived from 5 model experiments) with the two representative concentration pathways 4.5 (RCP4.5) and 8.5 (RCP8.5) were employed to project harvest dates for two future time windows [future projection 1 (FP1): 2041-2065 and future projection 2 (FP2): 2071-2095]. Pearson's correlation coefficient was used to investigate relationships between air temperature and harvest date. Statistical significance was set at $p< 0.05$.

Results - Harvest dates showed negative trends in six out of eight cases (four cases statistically significant) while in two areas (Crete and Pyrgos) harvest occurs later. In addition, harvest date – temperature analysis showed significant negative relations in seven out of eight cases. Rodos (cv. Athiri) was the only case with a significant positive relationship. Heat requirement analysis revealed that two varieties (cvs. Muscat of Alexandria and Moschofilero) needed almost 1700 GDD to achieve full maturity while the other two varieties (cvc. Mavrodaphni and Xinomavro) exceeded 2000 GDD units (2021 and 2049, respectively). Future projection analysis showed that harvest will shift earlier for all varieties (ranging approximately from one to two months) and this shift in both time windows will depend on the variety and the selected emission scenario.

Keywords:Grape variety, Heat requirements, Climate change, Regional climate models.

1. Introduction

It is widely accepted that climatic conditions primarily determine whether a given region is suitable for the production of premium quality wine from specific varieties. Thus, renowned winegrape regions are located in narrow geographic ranges. The potential effects of air temperature on vine developmental cycle, grape ripening potential, yield and wine quality have been widely documented over the last decades (Nemani et al. 2001, Jones et al. 2005, Ramos et al. 2008, Fraga et al. 2016, Koufos et al. 2017).

Future warmer projections could pose additional challenges on viticulture in Greece which is one of the oldest wine producing regions currently cultivated with over 200 indigenous varieties (Lacombe et al. 2011). To increase the resilience of the Greek wine sector to climate change, it is important to assess the thermal demands of Greek varieties in order to adapt future practices. Thus, the present study aims at investigating: (a) the potential role of ripening period air temperature on harvest dates for eight principally cultivated indigenous winegrape varieties (one for each winegrape area of Greece) and (b) varieties' thermal demands using the standard growing degree day (GDD) formula and project harvest date in two future time windows using a multi-Regional Climate Model ensemble dataset.

2. Material and methods

Harvest dates were assembled from four white [cvs. Muscat of Alexandria (Limnos), Assyrtiko (Santorini), Muscat blanc (Samos) and Athiri (Rodos)] and four red [cvs. Moschofilero (Tripoli), Mavrodaphni (Pyrgos), Mandilaria (Crete) and Xinomavro (Naousa)] varieties, covering a period from 11 to 44 years. Daily observations of maximum (TX) and minimum (TN) air temperature (^{o}C) were obtained from the Hellenic National Meteorological Service (HNMS) for eight principal wine producing areas and varieties (one for each area) across the Greek territory. Weather stations were selected based on their proximity to the vineyards.The primary climate parameters were used to calculate two bioclimatic indices widely used in viticulture studies: (a) average temperature (T_{avg}) [(i.e. T_{avg} = (TX + TN)/2] and (b) growing degree days (GDD, Winkler 1974). Air temperature variables (i.e. T_{avg}, TX and TN) were computed for ripening period (RP) which is described as the period of 45 days before harvest (Conde et al. 2007). The GDD were calculated using the standard formula [GDD = (T_{avg} - T_{base}), where T_{base} = 10^{o}C] from 1st of April to each of the varieties' observed harvest date. In order to project future harvest dates, daily simulations of future temperature time series with high spatial resolution (0.11^{o} x 0.11^{o}) were provided by the Data Extraction Application for Regional Climate (DEAR-Clima). Daily simulations from 10 regional climate models (derived from 5 global model experiments) were used to construct ensemble datasets (one for each area). The representative concentration pathway 4.5 (a:RCP4.5) and 8.5 (b:RCP8.5) were employed to project harvest dates for two future time windows [future projection 1 (FP1): 2041-2065 and future projection 2 (FP2): 2071-2095]. Basic linear regression models (Y = a + bX) were used to explore harvest dates trends through time. Pearson's correlation coefficient was used: (a) to estimate the temperature variables trends and (b) investigate relationships between air temperature and harvest date. Statistical significance was set at $p< 0.05$.

3. Results and discussion

The results of harvest dates and Pearson's correlation analyses are presented in Table 1. In four out of eight areas, a systematic shift (statistically significant trends) of harvest dates was identified (earlier harvest occurrence), mainly driven by changes in T_{avg} and TX (except for Samos).In the areas of Naousa and Tripoli (no significant negative trends), changes in TX were responsible for harvest dates variations (Table 1). Finally, Rodos (significant) and Crete (no significant) were the only areas with positive harvest trends.

Regarding varieties heat requirement analysis (Table 2), Muscat of Alexandria (Limnos) and Moschofilero (Tripoli) achieve full maturity at 1674 and 1701 GDD, respectively while Mavrodaphni and Xinomavro exceed 2000 GDD (2021 and 2049 respectively). The harvest dates of Moschofilero and Xinomavro [currently harvested in early October (DOY 277) – late September (DOY 268 in figure)] are projected to occur earlier by approximately three weeks (18 and 23 days, respectively) during FP1a and almost a month earlier considering FP1b (figure 1). Slightly milder responses were identified for Mavrodaphni and Muscat of Alexandria, currently harvested in early- to mid-September (DOY 259 and 247, respectively), during the FP1a (16 and 17 days, respectively) and FP1b (23 and 22 days, respectively). For the FP2a and FP2b periods, harvest is expected to shift earlier by 38 to 53 days depending the variety and the selected concentration pathway scenario.

4. Conclusions

This study examined the impacts of ripening period air temperature on harvest dates and assessed the thermal demands of important winegrape varieties in Greece. Average and maximum temperature were found to exert a significant impact on harvest dates (earlier occurrence) in the majority of the cases. Future harvest dates analysis showed that harvest will occur much earlier in the two examined future periods putting additional pressure on Greek viticulture. In this context, the correct choice of the variety according to its heat requirements will be a major adaptation strategy.

6. Litterature cited

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Table 1. Harvest trend and harvest – temperature Pearson correlation analysis. The number of years with available observations is also shown. Bold letters indicate statistical significance at 95% level (p – value < 0.05). TavgRP: average temperature 45 days before harvest; TXRP: maximum temperature 45 days before harvest and TNRP: minimum temperature 45 days before harvest.

Region (Variety)	Harvest evolution	Harvest – Climate correlation			Number of years with observations used
	trend (yr^{-1},days)	TavgRP (Pearson r)	TXRP (Pearson r)	TNRP (Pearson r)	
Crete (Mandilaria)	+0.4	**-0.68**	**-0.70**	-0.59	11
Limnos (Muscat of Alexandria)	**-0.6**	**-0.84**	**-0.81**	**-0.83**	44
Naousa (Xinomavro)	-0.1	**-0.76**	**-0.79**	**-0.61**	38
Pyrgos (Mavrodaphni)	**-0.8**	**-0.84**	**-0.82**	**-0.76**	29
Rodos (Athiri)	**+0.4**	**0.42**	**0.39**	**0.43**	28
Samos (Muscat blanc)	**-0.4**	-0.15	-0.05	-0.22	33
Santorini (Assyrtiko)	**-0.4**	**-0.41**	-0.38	-0.37	25
Tripoli (Moschofilero)	-0.5	**-0.57**	**-0.62**	-0.38	17TX

Table 2. Heat requirements (GDD) of the selected varieties. Total growing degree days and standard deviation (in parenthesis) is given for each variety.

Variety	Winegrape area	Heat requirements-GDD
Muscat of Alexandria	Limnos	1674 (76)
Xinomavro	Naoussa	2049 (148)

Mavrodaphni	Pyrgos	2021 (141)
Moschofilero	Tripoli	1701 (142)

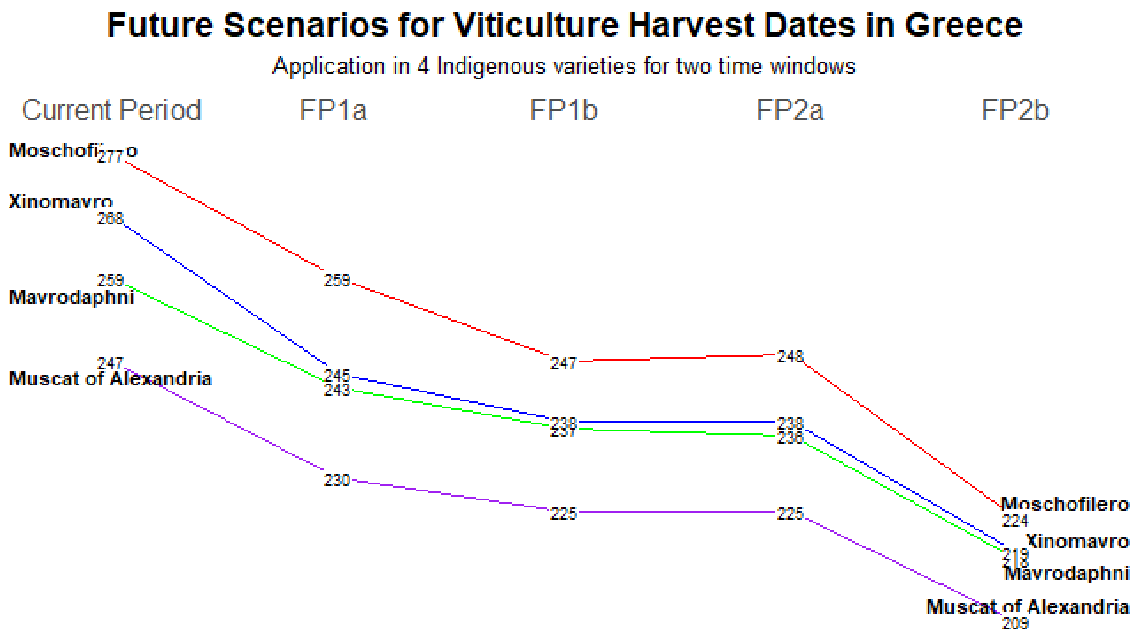

Figure 1. Harvest dates evolution by the end of the 21st century. A period analysis of the 4 selected winegrape varieties in Greece. The left conceivable vertical axis shows the current time of maturity of the selected varieties while the right conceivable vertical axis the future projection of maturity according to RCP scenarios and time windows used in this study: FP1a: Future Period 2041-2065 and representative concentration pathway 4.5; FP1b: Future Period 2041-2065 and representative concentration pathway 8.5; FP2a: Future Period 2071-2095 and representative concentration pathway 4.5; FP1b: Future Period 2071-2095 and representative concentration pathway 8.5. Number in graphs represents the time of maturity (harvest) according to Julian date (e.g. 277: 01-October etc).